

# MIT'S TECHNOLOGY REVIEW

**Can Computers  
Create Literature?**

**SELMER BRINGSJORD THINKS SO.  
AND HE'S TEACHING THEM HOW TO DO IT.**

MAR/APR 1998  
USA \$4.95  
CANADA \$6.50



# technology review

Published by MIT

This PDF is for your personal, non-commercial use only.  
Distribution and use of this material are governed by copyright law.  
For non-personal use, or to order multiple copies please email  
[permissions@technologyreview.com](mailto:permissions@technologyreview.com).

It's the way the city comes alive at night. It's a 3.5-liter, 210-horsepower engine that likes to show off more than a teenager. It's climate control that falls



©1997 Acura Division of American Honda Motor Co., Inc. Acura and RL are trademarks of Honda Motor Co., Ltd. Bose is a registered trademark of Bose Corporation. Make an intelligent decision. Buckle up. 1-800-TO-ACURA/www.acura.com

*The Acura 3.5RL*

somewhere between chemistry and artistry. It's a streetcar named desire. It's an 8-speaker Bose® audio system with a Ph.D. in music appreciation. It's the first satellite-linked navigation system built in-dash (so you'll never lose the directions). It's a car that knows you better than some people. It's the Acura RL.

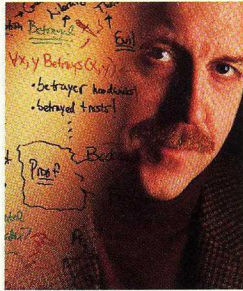
The True Definition of Luxury. Yours.™



MIT'S  
**TECHNOLOGY  
REVIEW**

MARCH/APRIL 1998

**FEATURES**



23

**23**

**COVER STORY**

## **Chess Is Too Easy**

**BY SELMER BRINGSJORD**

Forget about Big Blue vs. Kasparov—the best test of artificial intelligence is to ask a computer to write a story. Meet Brutus.1, a software agent that creates short tales of betrayal, self-deception, and evil worthy of a human creator.



29

**29**

## **Other Countries' Money**

**BY RICHARD FLORIDA**

Foreign companies are tapping into the vigorous U.S. system of innovation by sponsoring an increasing amount of research and development at American companies. Is this a boon, or a subtle form of industrial espionage?



38

**38**

## **Cashing In on Medical Knowledge**

**BY SETH SHULMAN**

Some doctors have begun patenting not just devices but medical procedures and techniques. Proponents argue that this practice is needed to foster innovation in medical care. Some critics, however, claim that it perverts the Hippocratic oath and drives up medical costs.



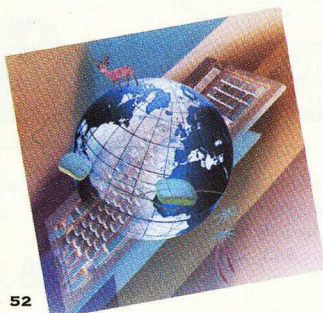
46

**46**

## **To Mac or Not to Mac?**

**BY DAVID SHENK**

A self-confessed Macintosh devotee contemplates the ultimate sacrifice: moving to a PC running Windows. Is life worth living on the Dark Side?



52

**52**

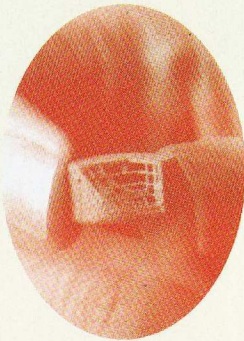
## **The Virtues (and Vices) of Virtual Colleagues**

**BY NANCY ROSS-FLANIGAN**

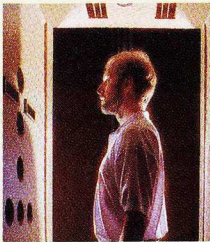
Electronic "collaboratories" that let researchers conduct experiments, review data, and communicate with colleagues via computer are changing the culture of science. But basking in a monitor's glow doesn't equal a firsthand look at an aurora borealis.

COVER PHOTOGRAPH BY WEBB CHAPPELL

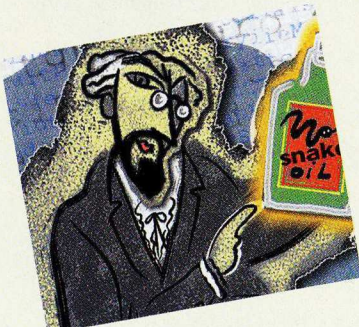
DEPARTMENTS



10



14



60



63

**5** **FIRST LINE:** Raising the Curtain on a New *TR*

**6** **LETTERS:** Bikes, Food, Bubbles

**10** **MIT REPORTER**

**10 PHARMACEUTICALS:** Precision Pills

**11 NUCLEAR MEDICINE:** Accelerating Isotope Production

**12 SEMICONDUCTORS:** Fungi Fodder?

**14** **TRENDS**

**14 ANTITERRORISM:** A Sniff in Time

**15 SEMICONDUCTORS:** Go for the Glow

**16 VIRTUAL REALITY 1:** Exploring the CAVE

**17 VIRTUAL REALITY 2:** Practice Makes Perfect

**19 MASS TRANSIT:** Back to the Future—with Monorails

**20 MATERIALS:** Waxing Hot and Cold

**60** **FORUM**

BY JUDITH G. HALL

FINDING THE WHEAT, LEAVING THE CHAFF. Medical information is readily available on the Web. So is misinformation. The general public is hard-pressed to tell the difference, though, placing a new burden on doctors.

**62** **THE CULTURE OF TECHNOLOGY**

BY LANGDON WINNER

PROPHETS OF INEVITABILITY. Human choices—not immutable forces of nature—govern the development and adoption of technologies.

**63** **REVIEWS**

**63** Wade Roush on CD-ROMS that set a new standard

**65** Norman Weinstein on Space and the American imagination

**66** **CLASSIFIED ADS**

**70** **CAREER OPPORTUNITIES**

EXPLORE THESE TOPICS AT:  
<http://web.mit.edu/techreview/>



## THE MERRILL LYNCH FORUM ANNOUNCES THE INNOVATION GRANTS COMPETITION

The Merrill Lynch Forum will award \$150,000 in grants to recent Ph.D. recipients from universities worldwide. Top prize is \$50,000.

In the 21st-century global economy, we believe that universities will be more important incubators of innovation and creators of intellectual capital than ever before. The Innovation Grants Competition seeks to encourage Ph.D. candidates to explore the marketplace potential of their dissertation ideas. In addition to cash awards, winners will meet with leading entrepreneurs and venture capitalists to discuss their work. The winning candidates' university departments will also receive \$5,000 Innovation Grants.

All Ph.D. candidates in the sciences, liberal arts and engineering who successfully defend a dissertation between January 1, 1996 and May 31, 1998 are eligible to enter the competition. Awards will be announced in September, 1998. Applications and entry information can be obtained from the Forum Web site at [www.ml.com/innovation](http://www.ml.com/innovation) or via e-mail to [InnovationGrants@ml.com](mailto:InnovationGrants@ml.com). Or call 1-888-33-FORUM.

An independent panel of distinguished scientists and entrepreneurs, under the direction of **Michael Schrage**, Research Associate of the MIT Media Lab, will judge the competition:

**John Seely Brown**, Ph.D., Chief Scientist, Xerox Corp.,  
Director, Xerox Palo Alto Research Center (PARC)

**Edgar W.K. Cheng**, M.D., Chairman, World-Wide  
Investment Company Limited and Former Chairman,  
The Stock Exchange of Hong Kong

**John Doerr**, Partner, Kleiner Perkins Caufield & Byers

**Esther Dyson**, EDventure Holdings, Inc.

**Peter Goldmark Jr.**, President, The Rockefeller  
Foundation

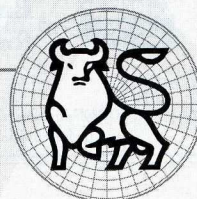
**William Haseltine**, Ph.D., Chairman & CEO, Human  
Genome Sciences, Inc.

**John Markoff**, Technology Correspondent, *The New  
York Times*

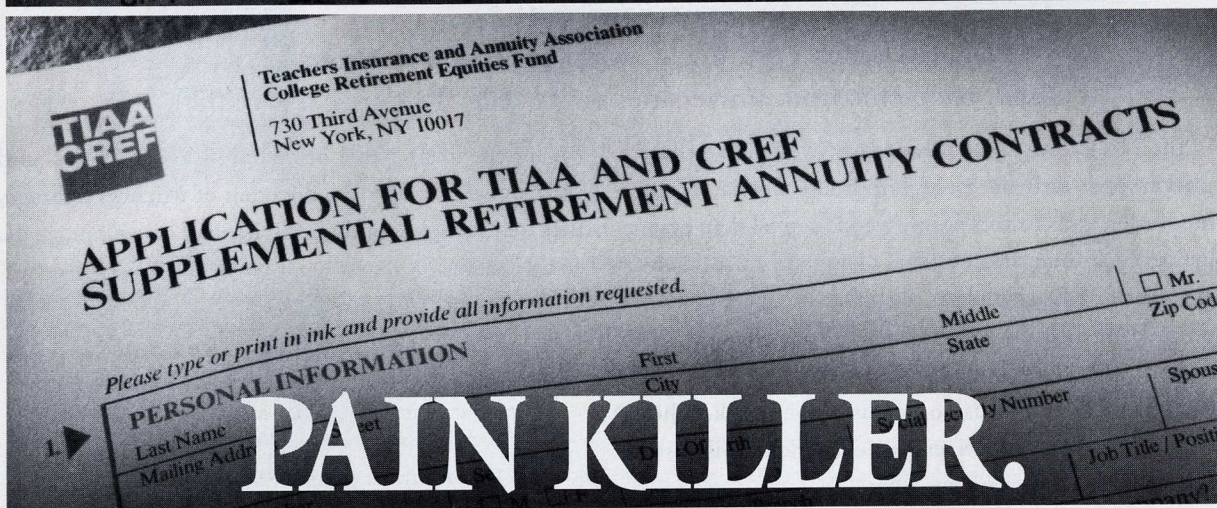
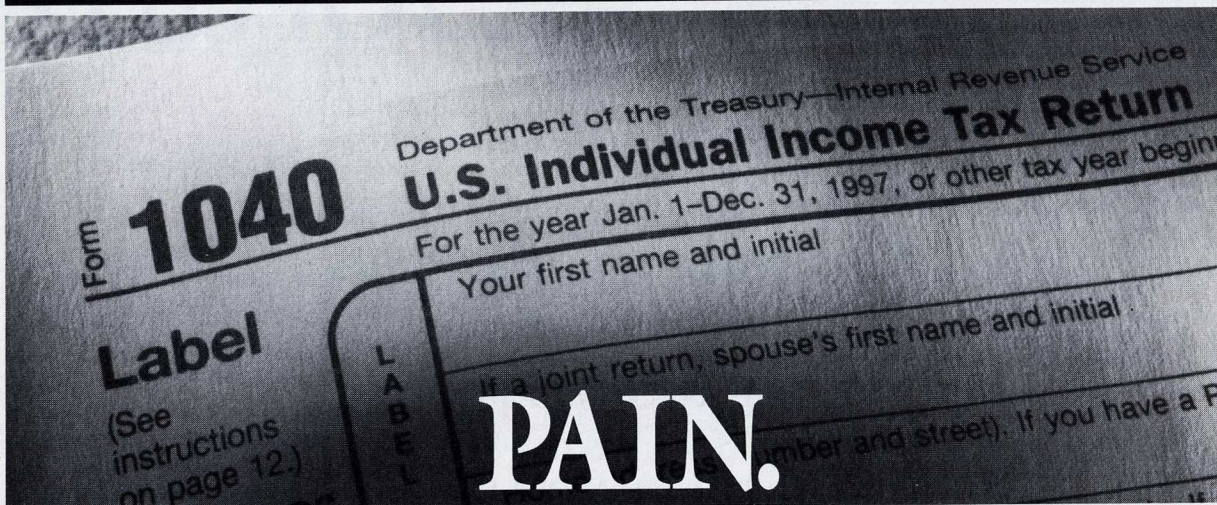
**Edward McKinley**, President, E.M. Warburg, Pincus  
& Company, International, Ltd.

**Arati Prabhakar**, Ph.D., Chief Technology Officer,  
Raychem Corp.

The Merrill Lynch Forum seeks to create a more vibrant marketplace of ideas, bringing together leading experts to consider and explore issues of worldwide importance in technology, economics, geopolitics and beyond.



## PRINCIPLES *of* SOUND RETIREMENT INVESTING



**F**or fast relief from the nagging ache of taxes, we recommend TIAA-CREF SRAs. SRAs are tax-deferred annuities designed to help build additional assets—money that can help make the difference between living and living *well* after your working years are over.

Contributions to your SRAs are deducted from your salary on a pretax basis, so you pay less in taxes now. And since earnings on your SRAs are also tax deferred until you receive them as

retirement income, the money you don't send to Washington can work even harder for you.

What else do SRAs offer? A full range of investment choices and the financial expertise of TIAA-CREF—the world's largest retirement organization.\*

To find out more, stop by your benefits office or give us a call at 1 800 842-2776. We'll show you how SRAs can lower *your* taxes.

Do it today—it couldn't hurt.

Visit us on the Internet at [www.tiaa-cref.org](http://www.tiaa-cref.org)



**Ensuring the future  
for those who shape it.™**

\*Based on assets under management.

TIAA-CREF Individual and Institutional Services distributes CREF certificates and interests in the TIAA Real Estate Account. For more complete information, including charges and expenses, call 1 800 842-2733, ext. 5509, for the prospectuses. Read them carefully before you invest or send money.

12/97

**I**N some ways putting out a magazine is a little like producing a play. We have our own scenery (our graphic design), a cast (our editors, writers, and graphic artists), and a script that we work from (the editorial focus of the magazine).

Right now it feels as if we're working hard here behind the curtain at 201 Vassar Street on the edge of the MIT campus to make sure that our production is ready to open on time, with everything polished and in place.

The new scenery (the graphic design that David Herbeck of *Civilization* magazine has been working so hard on) is almost complete. We've seen several rounds of preliminary designs from David for feature stories and the new departments, and we're all very pleased. The new design will be open, clean, contemporary, and highly readable—an excellent combination of cutting-edge style and the substance you expect from MIT.

The new cast is arriving now. Almost every Monday brings the arrival of a talented new player to our offices. By the time the first issue of the "new" *TR* is published, the cast and crew will be complete. The script that we're all working from—the magazine's new editorial structure—has gone through several rewrites and is just about ready for the public. The new arrivals are walking about backstage memorizing their lines and cueing one another if they forget.

A word or two about the script that we'll be working from. In response to my previous "First Line" column, in which I began talking about the new editorial focus of the magazine, I received some responses from one or two readers who were upset about the change. That's perfectly understandable. Change in familiar objects is inevitably disturbing, and *TR* has been not only familiar but of consistently high quality. Therefore, the concern is something that we sympathize with.

## THE CURTAIN GOES UP ON A NEW PRODUCTION

*Behind the scenes  
at 201 Vassar Street,  
a new cast arrives,  
the script is rewritten,  
scenery is painted . . .*

Yet there is one specific kind of concern that I would like to allay because I think it's unwarranted. That is the concern that *Technology Review*, in its new incarnation, will become a magazine that is, as some of you put it, "boosterish" about technology and that therefore fails to appreciate the implications and context of innovation. That isn't the case. Our new focus on innovation doesn't by any means imply that we will be talking only about the latest innovations and how they work. We will be discussing those issues, of course. We think they're important. But that isn't all we'll be talking about. Far from it. Our concept of innovation ranges widely to include the entire context of technology—personal, organizational, social, cultural, economic, global.

In fact, some of the most interesting thinkers about innovation today argue that it isn't possible to separate technology and human organization in any straightforward way. The most important examples of innovation, they argue, always combine hardware (and, today, software) with a specific

kind of human context. And *Technology Review* will be very sensitive to the human context. We'll be asking what kinds of organizations are capable of innovation and which are not. We'll be looking critically at the effects of innovation on society and culture. In our articles we will never forget that technology is a human activity and not a disembodied abstraction.

Indeed, without giving too much away, I would like to tell you that the very first cover story from the "new" *TR* (the May/June issue) will very much focus on the context of innovation: what corporations and society as a whole must do to remain successful during periods like the present that are marked by rapid innovation, economic globalization, and great volatility. I hope you'll find this exclusive piece a rich prologue to our efforts.

In addition to these changes in scripting, we are, as I mentioned above, going through changes in our cast of players. And I'd like to take this time and space to acknowledge and thank a group of seven people who have given a great deal of themselves to *Technology Review* during their tenure here. That group includes: Art Director Kathy Sayre, Senior Designers Nancy Cahners and Lori Nollet-Damon, Senior Editors Laura van Dam and Faith Hruby, MIT News Editor Susan Lewis, and Office Manager Peggy Shea. The high quality of *Technology Review*—along with its many awards and honors over the years—is due in large measure to the work of this group. We are grateful to them and we wish them well as they move on to new scripts and new scenery.

And now, ladies and gentlemen, take your seats. The curtain is about to go up on a new and vital production of an old favorite: *Technology Review*. ■

JOHN BENDITT  
EDITOR IN CHIEF

**EDITOR IN CHIEF**  
John Benditt

**SENIOR EDITORS**  
Herb Brody, Faith Hruby,  
Susan Lewis, Philip LoPiccolo,  
Laura van Dam

**ASSOCIATE EDITOR**  
Stephanie V. Grepo

**CONTRIBUTING EDITOR**  
Caroline T. Chauncey

**COPY EDITOR**  
Lucy McCauley

**OFFICE MANAGER**  
Margaret Shea

**DESIGN DIRECTOR**  
Kathleen Sayre

**SENIOR DESIGNERS**  
Nancy L. Cahners  
Lori Nollet Damon

**DESIGN/PRODUCTION ASSOCIATE**  
Valerie V. Kiviat

**COLUMNISTS**  
Samuel C. Florman, Bennett Harrison,  
Robert M. White, Langdon Winner

**CONTRIBUTING WRITERS**  
Debra Cash, David Graham, Seth Shulman,  
P.J. Skerrett, Jane Stevens,  
David Tenenbaum, Peter Tyson

**CHAIRMAN**  
William J. Hecht

**TECHNOLOGY REVIEW BOARD**

Christian J. Matthew (Chair)  
Woodie C. Flowers  
Bernard A. Goldhirsh  
Barbara Goldoftas  
William J. Hecht  
R. Bruce Journey  
Alan P. Lightman  
Victor K. McElheny  
Robert M. Metcalfe  
DuWayne J. Peterson, Jr.  
Philip R. Sayre  
Edward T. Thompson  
G. Mead Wyman

MIT's Technology Review  
201 Vassar St. W59-200  
Cambridge, MA 02139  
Tel: 617-253-8250  
Fax: 617-258-5850  
<http://web.mit.edu/techreview>

# Letters

## OPENING NIGHT REVIEWS

I am delighted with the promised change in focus of *Technology Review* which in the past exhibited a strong anti-technology bias. Technological innovation is the engine that will improve the health and well-being of all people. It is appropriate that a journal sponsored by MIT be an interesting, informative, and vibrant organ for explaining innovation and its implication to the public.

MAX T. WEISS  
Los Angeles, CA

I was very disappointed to learn of *Technology Review's* change in focus from policy to "innovation," which is likely to alienate many current readers.

I currently look forward to the arrival of each issue of *Technology Review*, because I know that it has few peers in discussing how policy affects technology. I appreciate the wide range of perspectives, from boosters to those reluctant about change. We don't need another boosteristic publication singing the praises of innovation.

MICHAEL ERNST  
Seattle, WA

## LOOKING BEFORE THE LEAP

Reading "Aviation's Next Great Leap" by Robert Zubrin and Mitchell Burnside Clapp (*TR January/February 1998*) gave me the impression that the authors were about to take their company public and were using the pages of *TR* as a publicity vehicle. They fail to mention, for example, the sonic boom that a rocketplane would produce. They also overstate the impact that such an aircraft would have on travel time; unless you live right next to an airport and are going to a similarly situated destination, it is the ground transportation which eats up much of the time. As far as package delivery, the Global Express model depends on a central hub and requires two trips; how does

the one-hour oceanic crossing make up for this problem?

FRANK WEIGERT  
Wilmington, DE

### *The author responds:*

Rocketplanes can circumvent the sonic boom problem by waiting to employ their rocket engines until they are at high altitudes and well away from land. The Pioneer rocketplane enables this strategy by employing ordinary jet engines for initial ascent, while the Kelly rocketplane uses a tow aircraft for much the same purpose. Unlike supersonic jet aircraft, rocketplanes spend most of their flight in an exoatmospheric or near-exoatmospheric condition, which eliminates sonic boom problems during mid-passage.

It is clear that a rocketplane would not save much time on a New York to Chicago run, where indeed much of the time is currently consumed getting to and through the airport. But on transoceanic routes, which today involve spending 10 to 18 hours in the air, the one hour flight time offered by rocketplanes would be a major advantage.

ROBERT ZUBRIN

## A FEW BUBBLES TOO MANY

I think somebody slipped a few decimal points in the article "Bubbles by the Billions" by Steve Nadis (*TR January/February 1998*). The story states that 10 billion of the bubbles, which are "less than 50 microns in diameter," fit into one cubic centimeter.

If exactly 50 microns in diameter, 200 bubbles side-by-side would span one centimeter. That means 8 million bubbles would fill one cubic centimeter. Admittedly, the number could be increased slightly by nesting alternate layers, but not to the 10 billion reported in the article.

ROALD CANN '51  
Springfield, VT

*We welcome letters to the editor.*

*Write: Technology Review, Building W59, Cambridge, MA 02139. Fax: (617)258-8778.*

*E-mail: <technology-review-letters@mit.edu>.*

*Please include your address, telephone number, and e-mail address.*

*Letters may be edited for clarity and length.*

*Nam Suh, head of MIT's engineering department, responds:*

The number of bubbles one can create in a given volume depends on the bubble diameter and also, when the bubble is not spherical, on bubble shape as well. We have made microcellular plastics that have uniform-sized bubbles in the range of 0.1 to 50 microns in diameter, which allows room for many more than the asserted 10 billion bubbles per cubic centimeter.

NAM P. SUH

Dept. of Mechanical Engineering, MIT  
Cambridge, MA

#### SOJOURNER'S SHIRLEY

This January *Ms.* magazine named Donna Shirley, manager of the Mars Exploration Program at NASA's Jet Propulsion Laboratory, one of their Women of the Year for creating and managing the Sojourner project. In "Honey, They've Shrunk the Rover" (*TR* January/February 1998), Eric Scigliano does not mention her at all. Why is there such a discrepancy in these two perceptions of Shirley's role in the project?

ANTONY AND ELIZABETH HODGSON  
Vancouver, BC, Canada

*The author responds:*

My article was concerned not with the Pathfinder/Sojourner mission but rather with the micro-rover evolution that preceded the mission and the vehicles that will perform future explorations. I certainly did not intend to diminish Donna Shirley's achievement, which has received much well-deserved attention. My main focus was what came before the mission and what may come after.

ERIC SCIGLIANO

#### NATURE'S WAY

"Food Irradiation: Will It Keep the Doctor Away?" (*TR*, November/December 1997) by P.J. Skerrett misses an important issue in the debate. Fresh food is alive—it has all its enzymes intact—and is exploding with flavor and subtle nutrition from its spores and bacteria. Even if irradiated food is proven harmless, it still lacks the full chemistry of life that it had

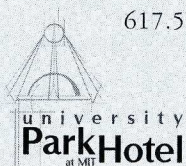
## NATURALLY, WE HAVE HOSPITALITY AND COMFORT DOWN TO A SCIENCE.



The proof lies in University Park Hotel at MIT, opening in the summer of 1998 and certain to be one of the area's most exclusive hotels. Here you will

find luxurious guest rooms with state-of-the-art amenities, such as dual telephone lines and data ports. Fine American cuisine and seasonal specialties at the avant-garde Sidney's Grille. Twenty-four hour room service. And an idyllic outdoor roof garden. Located in the heart of MIT, the hotel is also conveniently close to both Boston and Harvard Square. We invite you to put our hospitality to the test. For more information or to make a reservation please call

617.577.0200 or fax 617.494.8366.



**In A Class Of Its Own**

20 Sidney Street, Cambridge, MA 02139

e-mail: [welcome@univparkhotel.com](mailto:welcome@univparkhotel.com) website: [www.univparkhotel.com](http://www.univparkhotel.com)

MIT'S  
**TECHNOLOGY**  
REVIEW

**PUBLISHER  
AND CHIEF EXECUTIVE OFFICER**

R. Bruce Journey

Assistant to the Publisher/CEO, Elizabeth Surano

**ASSOCIATE PUBLISHER**  
Martha Connors

**ADVERTISING**

**Director of Advertising Sales**  
Paul Gillespie

Advertising Sales Assistant, Amanda J. Prugh

**New England**  
617-253-8229

Paul Gillespie  
pgillespie@mit.edu

**Mid-Atlantic/New York**  
212-213-6770

Yvonne Cooke,  
Karen Gleason Associates

**Southeast/Atlanta**  
770-993-7730

Tim Reis, *T. Reis & Co., Inc.*  
timreis@treisco.com

**Southwest/Dallas**  
972-991-4994

Phil Ganz, *The Ganz Company*  
philganz@ganzcompany.com

**Michigan/Detroit**  
248-816-9800

Mary Luongo,  
Kathleen G. Charla Associates  
kcharla@rust.net

**Midwest/Chicago**  
312-993-4111

Karen Gleason,  
Karen Gleason Associates  
moneymail@interact.com

**Northwest/San Francisco**  
415-398-7585

Gigi Volk,  
Magazine Services Inc.  
email@domain.com

**Southern California**  
310-641-6026

Skip Junis, *Junis Company*  
sjunis@juno.com

**CIRCULATION**

**Circulation Promotions Manager**, Cassandra  
McDermott; **Circulation Operations Manager**,  
Joan M. Frank; **Customer Service**, Ann Young

**MARKETING**

**Director of New Business Development**, Susan  
Tomases; **Marketing Coordinator**, Kristin Kelley

**Staff Accountant**, Letitia A. Trecartin; **Personnel  
Administrator**, Genevieve M. Hammond;  
**Information Systems**, Nelson Lee; **Staff Assistant**,  
Maia Balestrieri

MIT's Technology Review  
201 Vassar St. W59-200  
Cambridge, MA 02139  
Tel: 617-253-8250  
Fax: 617-258-5850  
trcomments@mit.edu  
<http://web.mit.edu/techreview>

**Subscriptions**: 800-877-5230, fax 617-253-5237,  
trsubscriptions@mit.edu; cost \$29.70 per year. Canada resi-  
dents add \$6, other foreign countries add \$12. **Questions**:  
617-253-8292, trsubscriptions@mit.edu. **Address Changes**:  
General 815-724-1207, traddress@mit.edu; MIT Records 617-  
253-8270. **Reprints and Permissions**: 617-253-8292,  
trcomments@mit.edu.

**LETTERS**



when it left the farm. Do we want to leave future generations a cornucopia of fresh-looking, food-like objects that have been irradiated to death for the industry's convenience and profit?

DAVID F. DOODY  
Pasadena, CA

Many readers are probably too young to remember when ripe produce could be purchased at a grocery store—it's been more than 20 years now. I bet the strawberries with a two-week shelf life (pictured on page 30) taste like cleaning chemicals. Every time food is processed, nutrients are lost. Grow a garden. Raise some chickens. Eat fresh food.

BRUCE BERRYHILL  
Eugene, OR

**ELEVATED THINKING**

I'm disturbed by the report of "heavenly" raised cycling highways (*Trends*, *TR* November/December 1997). It's a typical example of suboptimization: take care of the cyclists, seemingly reduce traffic and pollution, and speed people to their destinations. But what of the people who live along the way? All elevated highways degrade their neighborhoods. They cut their cities into pieces and degrade the avenues through which they pass. That's why Boston is putting its elevated Route 93 underground, why "els" were destroyed all over the U.S., and why here in Brussels the major city route went underground some years ago.

No matter how cost-effective Senior and Hawkes claim their plan is, buck per mile, the net city cost is huge. Cheaper: get rid of car lanes and give them to cyclists and public transport. Cost: painting lines and nailing up signs.

LESTER GIMPELSON  
Brussels, Belgium

Let's consider Boston's "heavenly" history. First we built elevated train lines from 1900 to 1920, which we have spent the 1940s to the present day

removing. An elevated six-lane Central Artery was proposed in 1930, it was built in the 1950s, and its destruction will last into the next decade. So now it's the bicycle's turn to blight the horizon with elevated structures. Will we ever learn?

As I understand the bikeway proposal, the Denver Company wants to pump air through the tunnel at 25 mph to blow the bicycles along. If 25 mph is good, why not higher? If we increase the speed to 100 mph, we could do away with bikes entirely and simply blow people through the tunnels at hurricane velocities.

STEPHEN H. KAISER  
Cambridge, MA

**A COMPLEX GENIUS**

In reviewing my book about Nikola Tesla (*Reviews*, *TR* November/December 1997), Lisa Gitelman writes that "Tesla's later claims of wizardry and his outlandish predictions about technology's future transformed him into a laughable figure during his lifetime." Gitelman overlooks much of the work that Tesla did in his later years. In his sixties, Tesla was working with companies such as Allis Chalmers to hone his bladeless turbine. At 66, he perfected an automobile speedometer that was used in the Pierce-Arrow and the Rolls Royce. At 72, Tesla returned to Philadelphia, where he tried to obtain funding to construct a prototype of his patented "flivver plane"—a combination helicopter/airplane. At 75, he worked with U.S. Steel on a power system that would run off the excess heat produced during steelmaking.

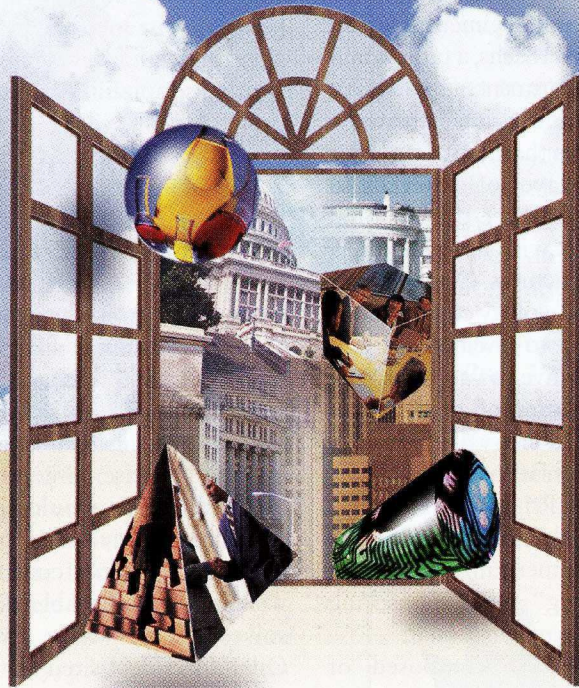
MARC J. SEIFER  
Adjunct Faculty  
Bristol Community College  
Fall River, MA



**CORRECTION:**

Our last issue, January/February 1998, was Vol. 101/No. 1.

# We help turn innovation into successful business.



*At Brobeck, we work with leading entrepreneurs to transform ideas into business opportunities.*

From business planning and raising capital, to protecting intellectual property assets and negotiating partnering deals, our attorneys provide the expertise and the experience needed to support the growth of your company.



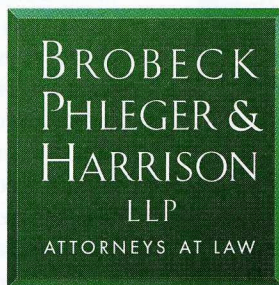
Andrew Busey, *Founder, Chairman & Chief Technology Officer. ichat, Inc.*, is ahead of the game. Four years ago and fresh out of Duke University, Andrew had the idea of creating

technology which would make real-time communications on the Internet as user friendly as a chat room on AOL.

Today, ichat's client-server technology is changing the way businesses and consumers communicate

and collaborate. ichat's software allows users of the World Wide Web and corporate Intranets to chat, send instant messages, post bulletins, and conduct serious on-line conferences.

"I was 22 when I first pitched my idea to the venture capital community. At that time, there wasn't really a tradition of young Internet entrepreneurs being successful, as the market was very young. Brobeck's track record in working with entrepreneurs is exceptional. Brobeck provided us with introductions to the VC community and helped me secure the funding to get ichat started," says Andrew.



Visit our website at  
[www.brobeck.com](http://www.brobeck.com)

## CALIFORNIA

SAN FRANCISCO  
(415) 442-0900

PALO ALTO  
(415) 424-0160

LOS ANGELES  
(213) 489-4060

NEWPORT BEACH  
(714) 752-7535

SAN DIEGO  
(619) 234-1966

## TEXAS

AUSTIN  
(512) 477-5495

## NEW YORK

NEW YORK  
(212) 581-1600

## COLORADO

DENVER  
(303) 293-0760

## LONDON

BROBECK HALE AND  
DORR INTERNATIONAL  
44 171 638-6688

## AN INSIDE LOOK AT RESEARCH AT MIT

### PHARMACEUTICALS

## Precision Pills

People who take pills for chronic diseases face schedules that would give an air-traffic controller pause: one kind of medication three times daily with meals, for instance, a second mid-morning and mid-afternoon, and a third at bedtime, as well as several others at various hours.

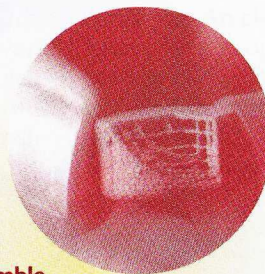
Michael Cima, a professor in MIT's department of materials science and engineering, has found a way to use computerized printing technology to simplify the lives of people who must fol-

**Conditions like high blood pressure peak in the morning. Computer-"printed" pills allow drug levels to peak just at the time medication is most needed.**

low these regimens. He and Emanuel Sachs, a professor in the department of mechanical engineering, have created a process that impresses layer upon layer of materials to yield three-dimensional objects with intricate internal structures. Cima believes the technology could make it possible to develop single pills that deliver a variety of specific doses of medicine at planned intervals. The pharmaceutical company Therics, of Princeton, N.J., has secured the exclusive license to commercialize "3-D drug printing" and is sponsoring Cima's research on it.

Pills are composed of drugs and "excipients"—binders and powders that control the release of medication in the digestive system. The usual procedure is to compress a simple mixture of these ingredients into tablet form. By contrast, the approach chosen by Therics calls for 30 to 50 layers of excipients; within such a

**Using a process similar to ink-jet printing, manufacturers can assemble a pill layer by layer, with precise amounts of medication deposited at specific locations.**



improved dosage control. With traditional pharmaceuticals manufacturing, a drug may not always be evenly distributed among excipients; different pills can wind up with somewhat different doses. But in the new process, the drop-on-demand nozzle used to

deposit medication would assure accurate doses in every tablet, Cima notes.

And 3-D drug printing might help companies bring more drugs to market. The reason, Cima says, is that the technology would permit them to take better advantage of "combinatorial chemistry," a means of rapidly testing the efficacy of molecules for a particular use. Combinatorial chemistry has doubled the number of possible therapeutic agents in R&D pipelines. But finding appropriate molecules is only the first step in drug development. Researchers must combine them in the right way with the right excipients—and therein lies a problem.

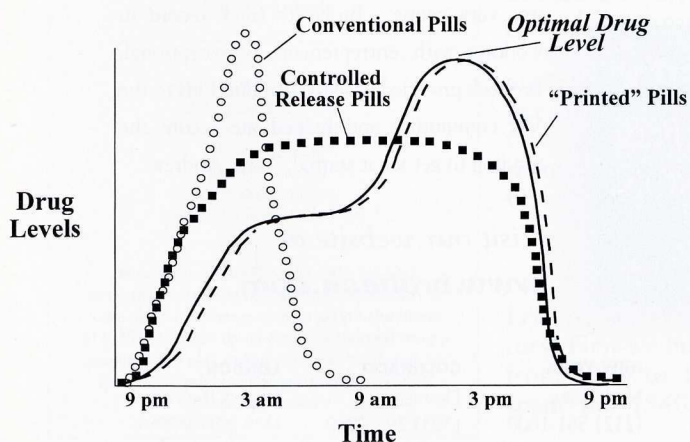
Firms must run trials on several subtly different combinations of drug and excipients. The use of conventional technology, which is designed to produce a large volume of pills at one time, requires making many more than are needed for each trial. Since the number of new drugs in the pipeline has

matrix, precise amounts of medication would be deposited in key locations. That way "we can control which portion of a tablet dissolves where," Cima says. One dose deposited in a tablet's outer layer might be unleashed after, say, an hour, while a dose buried deeper might come into play later.

According to C. William Rowe, an MIT visiting scientist from Therics, a wide range of pill-popping regimens could become less burdensome. Cancer patients could take one pill for both chemotherapy and the ensuing nausea. The technology could also help patients with conditions such as high blood pressure, for which required levels of medication change over the day. "The pressure peaks when these people get out of bed in the morning, so ideally you would like to deliver a high level of medication at exactly that time, and our technology could do this," Rowe says.

Another benefit could be

### Drug Delivery Patterns for Treatment of Hypertension



been doubled, the cost of conventional pill-making methods for drug trials could be prohibitive. But the new, three-dimensional method could allow researchers to produce small batches of pills with different formulations, sharply reducing waste.

Although various technical challenges still must be overcome, Cima says Therics is poised to start the first stage of tests for commercial production, so that "pills made this way might be available as soon as a year from now." Therics's Rowe is more guarded, stressing that the U.S. Food and Drug Administration (FDA) has yet to approve the process. But the difference between receiving approval for a manufacturing process, as opposed to getting it for an actual drug, is significant, Cima remarks. "It's sort of like going to the FDA and saying, 'We have a new pill press here.' The list of issues they want to look at is fairly short."

—BETH HORNING

#### NUCLEAR MEDICINE

### Accelerating Isotope Production

If you ran a business that depended on a critical component, how would you feel if the supplier were an aging factory—and no other producer existed? Not good probably. But you might feel better if some enterprising engineers invented a way around the bottleneck. And if the new method generated less waste than the old one, so much the better.

That's just what's happened in the case of technetium-99 (Tc-99), a radioactive isotope that is the workhorse of such medical-imaging techniques as single-photon-emission computed tomography. The sole North American source for the isotope is a 40-year-old nuclear reactor in Canada. Temporary shutdowns in 1991 and again last year threatened the supply, sending shock waves through the medical community, says S. James Adelstein, a Harvard University professor of medicine who chaired a 1995 Institute of Medicine report on medical isotopes.

"I think it is intolerable that we are basically being held hostage by one nuclear reactor," adds MIT's Lawrence Lidsky, professor of nuclear engineering. So he and his colleagues have developed a way to make Tc-99 and other isotopes that bypasses nuclear reactors. This new method would allow the United States and other countries to develop domestic supplies while minimizing the amount of radioactive waste generated by isotope production.

Technetium was the first artificial element. One of its 17 isotopes, Tc-99 is used in more than 10 million medical procedures a year in the United States alone, according to the Institute of Medicine. With a six-hour half life it doesn't linger in the body. It can be attached to a medley of carrier molecules and delivered to the bones, heart, kidney, gastrointestinal tract, thyroid gland, central nervous system, and virtually any other body part. Once inside its target, Tc-99 radi-

# Be rewarded for your great ideas

*The BFGoodrich Collegiate Inventors Program recognizes university students and their faculty advisors for research and innovative discoveries.*

- Open to any full-time student at a U.S. college or university
- Separate judging for both undergraduate and graduate students
- Cash prizes awarded totaling up to \$42,000
- Winners are honored alongside inductees of the National Inventors Hall of Fame in September

**DEADLINE FOR APPLICATIONS:**  
**June 2nd, 1998**

*For information and an application call Paul Kunce at 1-800-968-4332 or...*

Access the World Wide Web site to download an application at <http://www.invent.org/bfg/bfghome.html>



**Inventure Place**  
National Inventors Hall of Fame

*This program is sponsored by The BFGoodrich Company and administered by Inventure Place*

ates just enough energy to scintillate a scanner, but not enough to damage tissue.

The traditional technique for making Tc-99 begins with a small rolled sheet of so-called weapons-grade uranium. The sheet bakes in a special nuclear reactor where, under intense neutron bombardment, the uranium atoms split into tens of fission products. Technicians then chemically separate any molybdenum-99 that has formed. They dispose of everything else—a grab bag of nasties that includes plutonium, cesium, and strontium-90—as high-level radioactive waste. Finally they pack the purified molybdenum-99 into containers officially called generators but informally dubbed “cows,” that are shipped to radiopharmaceutical companies and hospitals and “milked” every few hours for the Tc-99 that accumulates when the unstable molybdenum-99 nucleus ejects a electron.

This process, now the industry standard, has several drawbacks. “It starts with weapons-grade uranium, requires a nuclear reactor, and finishes with radioactive waste,” says Lidsky. Therefore he and his colleagues in the nuclear engineering department tried approaching molybdenum-99 from a different direction, relying on a well-established principle of theoretical physics called giant dipole resonance.

The MIT process starts with readily available, stable molybdenum-100 and a linear accelerator. Focusing an accelerator’s beam of high-energy electrons onto a small

bar of tungsten generates x-rays, which consist of photons. A photon with the right energy can then slip inside the nucleus of a molybdenum-100 atom and shake up the neutrons and protons, Lidsky explains. The nucleus begins to resonate, or vibrate, and eventually ejects a neutron, becoming molybdenum-99 in the process.

In tests at MIT, the National Institute for Standards and Technology, and the Idaho National Engineering Laboratory, this approach produced enough molybdenum-99 to make commercial generation physically possible. “What really surprised us was that the cost was competitive with the highly subsidized price of molybdenum-99 from Canada,” says Lidsky, who had not focused on competitive pricing as a goal.

Lidsky’s alternative may not immediately replace the Canadian supply. To do so, it would have to cost less than current supplies, a difficult task given a heavily subsidized and well-established competitor that needn’t pay the full cost of disposing of radioactive waste. An accelerator-based method, however, could offer a reliable backup in case the flow of molybdenum-99 from Canada dries up, according to Lidsky. And this process “contains all the ingredients for a developing country looking to manufacture its own supply of isotopes without having to build a nuclear reactor or accept shipments of weapons-grade uranium,” says Armando Travelli, who manages the reduced-enrichment-reactor program at Argonne

National Laboratory.

Now that Lidsky’s team has proved the neutron-removal concept, it is turning to other medical isotopes. The linear-accelerator method can, for example, generate isotopes that can be made into tiny seeds implanted into prostate, ovarian, and other cancers. The seeds irradiate and kill tumors from the inside out. This method can make isotopes used to ease the racking pain caused by bone cancer. It may also be able to generate isotopes that emit alpha particles (those capable of giving off a helium nucleus) that monoclonal antibodies can deliver directly into cancer cells. This requires a particle with short penetrating ability; alpha particles travel shorter distances than other particles. And, at least in theory, it can make new medical isotopes which can’t be made by any other method and that have yet-unidentified uses.

“Now that we’ve developed the hammer,” says Lidsky, “we are looking for and finding new nails.”

—P.J. SKERRETT

## SEMICONDUCTORS

### Fungi Fodder?

Fungi. They decimate Dutch elm trees and disfigure toenails, blacken bread and rot logs. And that’s not all. A group of researchers at MIT and Harvard University have now shown that the same culprits can corrode the protective polymer coatings that package and insulate complex integrated circuits. If this

work holds up, it may suggest an explanation for the unexpected failures that sometimes plague electronic systems.

Complex electrical circuits resemble a club sandwich, with chips and wires smothered between insulating layers of polymers called polyimides. The aerospace and electronics industries rely on polyimides because they are strong and lightweight, repel moisture, stand up to high temperatures and flames, and resist ultraviolet rays and other damaging atmospheric radiation.

Makers and users of integrated circuits have also assumed that polyimides fend off attacks by microbes such as fungi. But in 1990 Bryce Mitton and Ronald Latanision, materials scientists in MIT’s Department of Materials Science and Engineering, noticed “white stuff” growing on polyimides used in their laboratory. The matter looked fuzzy under a microscope. They teamed up with Ralph Mitchell and Ji-Dong Gu, microbiologists at Harvard’s Laboratory of Microbial Ecology in the Division of Engineering and Applied Sciences, who identified it as a mixture of fungi, especially one called *Aspergillus versicolor* that is commonly found in air and water.

The MIT/Harvard group didn’t know whether the fungi growing on polyimides were pernicious. To find out, they constructed simple test circuits coated with polyimide insulation and deliberately contaminated some with fungi, keeping the rest sterile. The scientists then

measured the degradation of the polymer by monitoring the loss of electrical resistance. Polymer coatings with high resistance are good insulators. Compared with sterile samples, the insulating ability of the contaminated samples decreased rapidly. In fact, half the contaminated samples failed in one month, whereas the sterile samples took six months to fail. Such degradation in an electronic chip "could be bad news because you might get a short circuit," says Mitton.

The extensive fungal networks the MIT/Harvard group found may be destructive in three ways, the researchers suggest. First, the fungi use some chemical in polyimide as a nutrient, which the researchers hope to identify. That substance causes the coating to break down while enabling the organisms to grow filaments—hyphae—which branch and tangle in masses called mycelia that look like disorganized spider webs.

"The mycelia grow into small spaces beautifully. If you have even one hypha running down through an insulator carrying water, you have a wonderful short circuit," says Mitchell. Moreover, the fungi also release highly corrosive waste products such as hydrochloric acid and sulfuric acid.

The MIT/Harvard researchers stress that all their findings have come from laboratory work and need reproducing to verify that they're not the product of some quirk. But should the findings hold up, they might explain mysterious failures in

electrical systems. "Often electronics fail and no one knows why," says Mitchell. A theoretical worst-case scenario could involve dysfunctional circuits controlling military aircraft.

While high-risk systems generally have back-up electronics, the concern remains real—especially for circuits exposed to high humidity. "Fungi love moisture," explains Mitchell. System designers often leave electronics unsealed to make changing chips and components easy, he notes.

Producers of electronics may have recently added to any problem by a change in

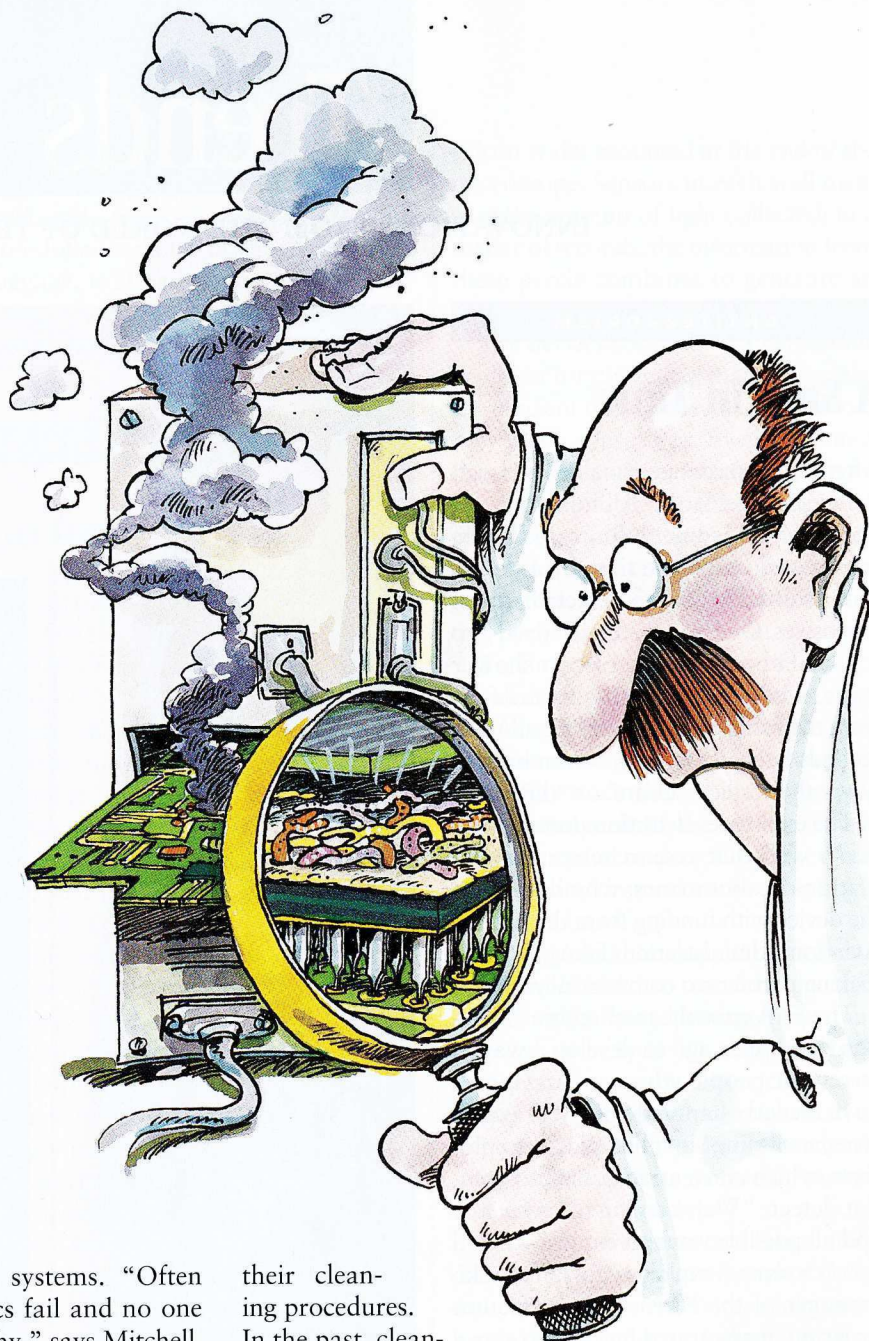
their cleaning procedures.

In the past, cleaning agents used in the manufacturing process contained chemicals such as chlorofluorohydrocarbons, which damage the ozone layer surrounding the earth. To become environmentally friendly, in recent years manufacturers have switched to water-based cleaning products. Unfortunately, water is rarely completely free of contaminants. Mitton has consistently found contamination in supposedly pure water, coming from a variety of labs, that has undergone stringent cleaning to

eliminate microbes. "I don't think it's possible to get rid of everything," says Mitton. "Just leaving water exposed to air will probably contaminate it," since fungi are everywhere.

Should future scenarios confirm that electronics can fail from fungal corrosion, Mitchell suggests that circuit designers could minimize moisture by sealing systems or lowering humidity.

—CAROL POTERA



# Trends

INNOVATIONS FROM THE WORLD OF TECHNOLOGY

## ANTITERRORISM

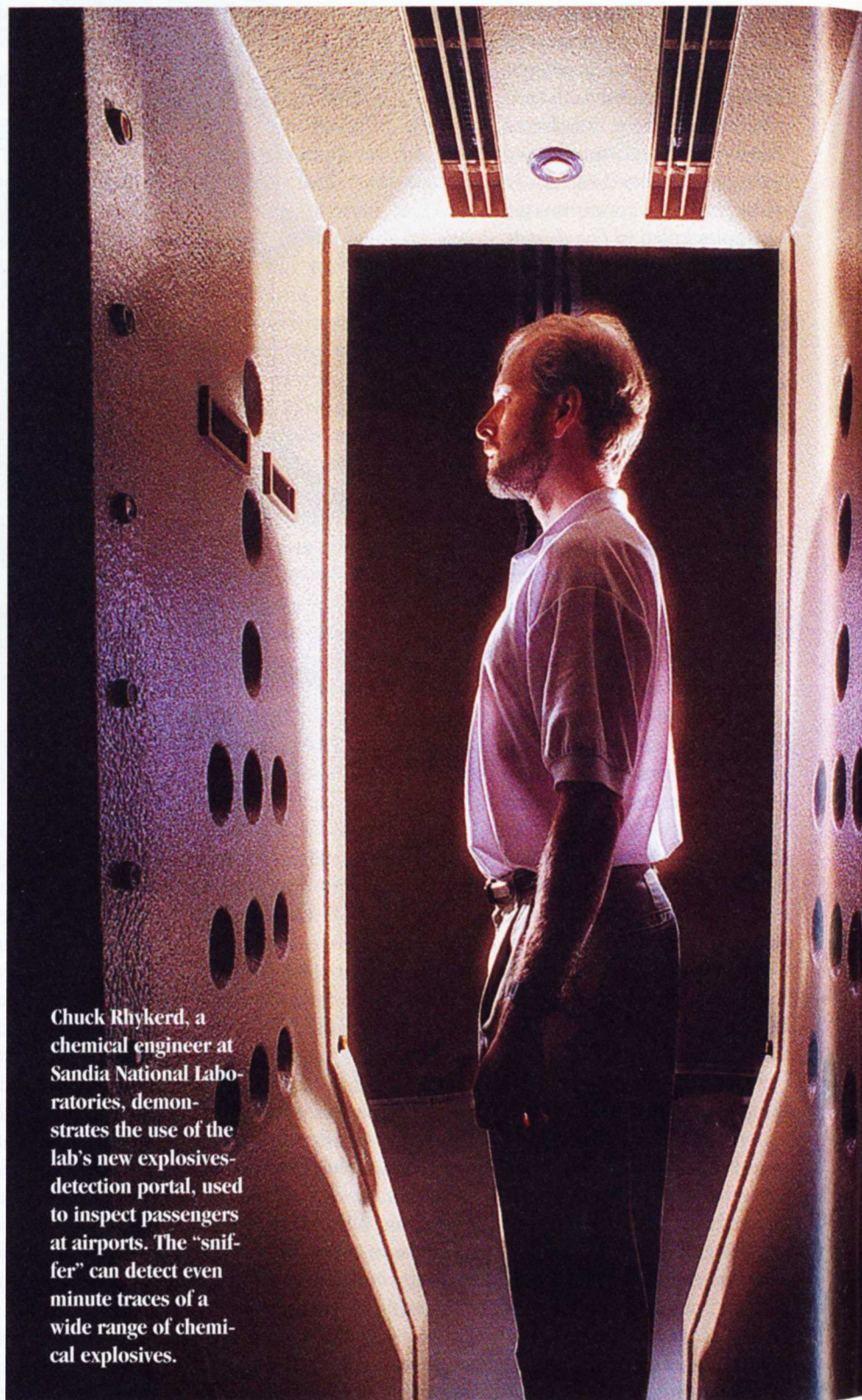
### A Sniff in Time

After airline passengers walked through the metal detectors at Albuquerque airport last fall, some volunteered to be scrutinized one more time by a device that “sniffed” them to detect chemical explosives. One by one, they stepped into a portal about the size of two shower stalls, where nozzles puffed jets of air from their shoulders to their knees. A few seconds later, a computer screen handed down the verdict: “clean” or “dirty.”

The explosives-detection portal worked so well that researchers at Sandia National Laboratories, who developed the device with funding from the Federal Aviation Administration (FAA), are now seeking partners to commercialize it.

The FAA gave the researchers \$2 million three years ago to develop a way to ferret out people who are carrying or have recently handled chemical explosives, including so-called plastic explosives, which conventional methods cannot detect. “We’re trying to cover any and all possible ways an explosive could get on a plane,” explains Paul Jankowski, manager of the FAA’s trace detection program, inaugurated in 1992 to stay a technological step ahead of terrorists.

The device is based on technology Sandia scientists developed to protect nuclear weapons facilities from bomb threats and to prevent people inside the facilities from smuggling out restricted chemical devices. It sprays several cubic feet of air over a person’s hands and clothes to dislodge any chemicals adhering to them. The air is sucked into a device below the traveler’s feet and passes through a chemical sensor called an ion mobility spectrometer that can identify the chemical signatures of many different types of explosives. The quantity and type of chemicals detected then appear on a computer screen.



Chuck Rhykerd, a chemical engineer at Sandia National Laboratories, demonstrates the use of the lab's new explosives-detection portal, used to inspect passengers at airports. The “sniffer” can detect even minute traces of a wide range of chemical explosives.

The challenge for Sandia's research team was to develop the preconcentrator technology—the part of the device that aggregates the air molecules quickly enough so that the ion spectrometer can analyze them. The team succeeded so well that the device can detect very small concentrations of all “explosives of interest” to the FAA, according to project leader Kevin Linker, a mechanical engineer. Naturally, given the task at hand, neither Sandia nor the FAA will reveal what types of explosives the device detects or its sensitivity.

Although the initial test, on 2,500 volunteers, worked well, members of the research team say the process—at 12 seconds per customer—still takes too long.

“Our goal is 6 to 10 seconds,” says chemical engineer Chuck Rhykerd. “That’s the current speed of metal detectors. It doesn’t seem that long, but once you take your keys out of your pocket, put your bags on the conveyor belt, walk through slowly, and pick up your bags, that’s how long it takes.”

Reducing the speed will be a challenge, he admits. “Five seconds to collect the air. Five seconds to do the analysis. We can probably cut the analysis time by one to two seconds. But cutting the sample time may reduce the device’s sensitivity. It’s a trade-off.”

Another glitch that researchers hope to fix before the device can go into production is that the machine occasionally sounds a false alarm. As for what causes the false positives, the security-minded Rhykerd says: “I have a suspicion, but I can’t tell you.”

Rhykerd believes that ultimately, the rate of false positives can be held to 5 percent, “well below” that of metal detectors. In addition to improving its accuracy, Rhykerd and his colleagues hope to overcome two other technical challenges: decreasing size and cost. The machine is bound to be expensive,

but the benefits could also be high. By way of comparison, the FAA’s Jankowski notes, the CTX5000, a million-dollar machine designed to inspect luggage, is already in use at some airports. “And this device is nowhere near that expensive,” he adds.

—JANE STEVENS

## SEMICONDUCTOR INDUSTRY

### Go for the Glow

Astronomers at San Diego State University (SDSU) have made a name as builders of electronic light detectors for many of the world’s great telescopes—among them the Keck telescope in Hawaii and the Hale on California’s Palomar Mountain. Now these astronomers have aimed their technology at a new target: computer chips. Mounted on microscopes rather than telescopes, the detectors can find flaws in computer chips more easily—and potentially more cheaply—than existing methods.

In an industry where small technological improvements can make a big difference in profit margins, these detectors, which are sensitive to radiation in the infrared part of the spectrum, could have a significant impact.

“We think it should be quite useful,” says Robert Leach, an SDSU astronomer who helped pioneer electronic imaging devices for telescopes in the 1980s with SDSU engineer Frank Beale. Recognizing the range of potential applications, Frank Low, president of Infrared Laboratories of Tucson, Ariz., began working with SDSU scientists in the spring of 1996 to develop infrared detectors for use in chip manufacturing. The infrared emission microscope they developed, known by the acronym IREM 1, went on the market last fall.

IREM 1 is descended from an infrared detector Low’s company built that is now flying on the Hubble Space Telescope. As the microscope passes over the surface of a computer chip, any infrared radiation (heat) emitted by the chip collects in the 65,000 wells, or pixels, of a

silicon wafer mounted at the end of the microscope. Sensors in each well measure the amount of light collected; in a matter of seconds, the information from these pixels combines to generate an image on a computer monitor.

The devices could solve a nettlesome problem for computer manufacturers, the efficient testing of new chips before they reach consumers. Even the tiniest flaw in a computer chip—perhaps a fleck of dust built into the circuitry or a place where insulation has eroded—can make electrical current jump between transistors, leaking heat and undercutting performance, Low explains.

To find such flaws, manufacturers put their chips through a series of tests, including running current through them and scrutinizing them with detectors of light. But since flawed chips give off more heat than light, the leakage of heat is much easier to detect. “In fact, the effect is fairly dramatic—the thing lights up,” says Leach.

He suggests that chip manufacturers could use IREM 1 to scan for chips that are obviously flawed, saving more complicated and expensive tests for chips that pass this crude “first cut,” and argues that the new device might lead to improvements in chip design by identifying recurring flaws in specific microcomponents on the chip.

Such improvements are “absolutely critical to the competitiveness of these companies,” says Jeff Weir, a spokesman for the Semiconductor Industry Association, the principal trade association for American chip manufacturers. “Anything that makes it quicker and easier to find a faulty chip is important. Things that can expedite production are money makers.”

According to Low, the inventors have already sold IREMs to two companies, one of which bought several of the devices. The first to buy them, one of the world’s largest chipmakers, is testing the device in its production process. (Low declined to name the companies, citing confidentiality contracts.)

Infrared Labs is now planning a second-generation array that will be dramatically faster than the the IREM 1.

With 16 times as many pixels—1.04 million compared with the IREM 1's 65,000—it will enable the device to view 16 times as much chip space at once.

—DAVID GRAHAM

## VIRTUAL REALITY 1

### Exploring the CAVE

Late last spring, engineers at Searle, the pharmaceutical subsidiary of Monsanto, discovered a design problem in a factory the company was planning to build. Two pipes on top of a piece of equipment called a fluid bed drier would stand 6.08 meters tall, but the ceiling would be only 6.05 meters high. To figure out whether they needed to raise the ceiling, engineers would normally have to roll out a jumble of blueprints and spend hours comparing architectural and equipment drawings.

Manufacturers such as Searle, Inc., are planning to telecollaborate on factory design by using a virtual reality theater known as the CAVE, developed at the University of Illinois. This simulated image of Prashant Banerjee, associate professor of mechanical engineering at the University of Illinois, is projected into a virtual factory floor environment.



MIT Professional Institute, 8-201  
Cambridge, MA 02139-4307  
Phone 617-253-2101 • Fax 617-253-8042  
professional-institute@mit.edu  
<http://web.mit.edu/professional/summer/>

#### Managing Strategic Uncertainty:

Military, Political, and Corporate Planning for the Post Cold War World

July 20-24, 1998

Harvey M. Sapolsky  
Michael Brown  
Owen R. Cote, Jr.  
Barry Posen  
Ted Postol  
Richard Samuels  
Stephen Van Evera  
Sanford L. Weiner

As the new century breaks so too will a new strategic environment. How will power shift? Where are the points of leverage? How can industry anticipate the changes? What are the strategic options? How can you stimulate innovative responses from your organizations? Members of the MIT Security Studies Program and selected associates help sort the planning issues. The focus is on conflict, budgets and the behavior of real organizations.

#### Promoting Innovation: The Dynamics of Technology and Organizations

July 13-16, 1998

Harvey M. Sapolsky  
James P. Womack  
Sanford L. Weiner  
Paul Levy  
James L. Foster  
Owen R. Cote, Jr.

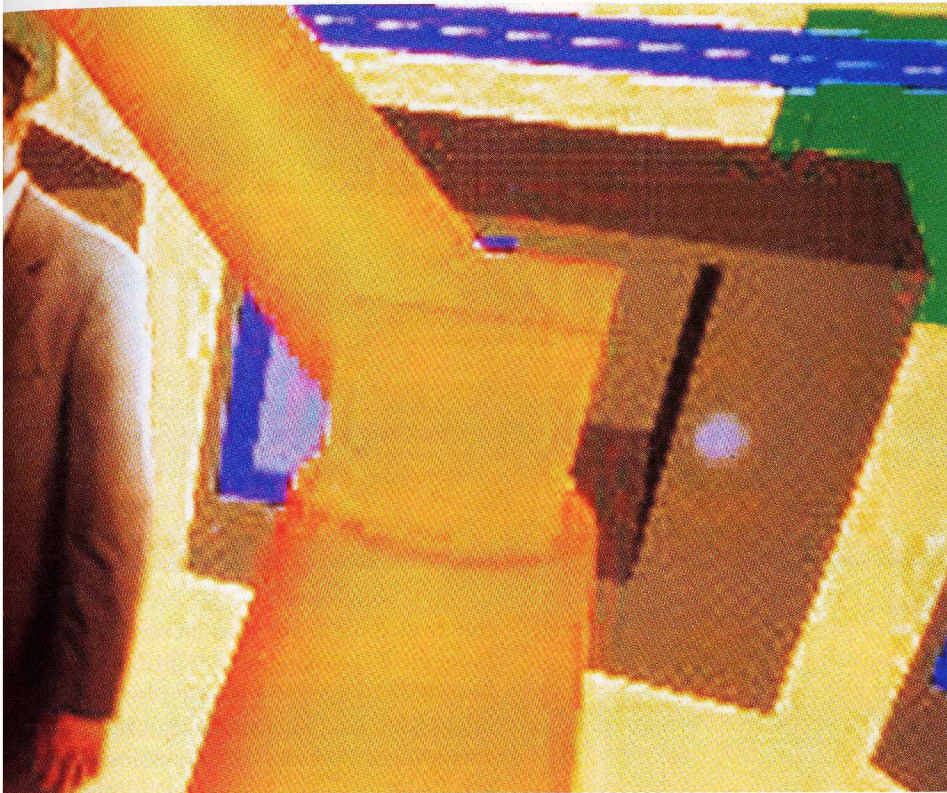
Successful innovation links technical advances to organizational change. MIT faculty and research associates lead intensive case studies of innovation in the energy, telecommunications, defense, chemical and automotive sectors. Other topics include lean engineering, public-private interrelationships, restructuring markets and organizational strategies for change.

#### SUMMER PROFESSIONAL PROGRAMS

"Nine times out of ten in this situation, you're looking at structural steel drawings from a different contractor from the one who designed the equipment," says Brian Dodds, director of manufacturing engineering for Searle, based in Skokie, Ill. "The two sets of drawings are not to the same scale, and they are not combined on one piece of paper, so it's difficult to marry up the different elements visually." That difficulty translates into time and money.

This time, however, the engineers donned 3-D glasses and stepped into a room-sized virtual reality theater at the University of Illinois at Chicago known as the CAVE (Cave Automated Virtual Environment, an allusion to Plato's parable of the cave, exploring perception, reality, and illusion). When they inspected the virtual ceiling and the virtual fluid bed drier, they were relieved to discover that the pipes on top of the equipment would fit perfectly into a gap between steel girders in the ceiling.

Searle is one of a handful of U.S. companies that are beginning to discover that virtual reality technology can save



them millions of dollars in design and construction costs—even before the first shovel of dirt is turned.

Developed in 1992, CAVE is the brainchild of Thomas DeFanti, a professor of electrical engineering at the University of Illinois at Chicago, and UIC art professor Daniel Sandin, now codirectors of the university's Electronic Visualization Laboratory (EVL). The million-dollar theater is a room approximately 3.2 meters square and 2.7 meters high. High-resolution 3-D video graphics from a Silicon Graphics workstation are projected in stereo on the walls and floor and viewed with stereo glasses.

Six months ago, Searle gave researchers at the university's mechanical engineering department \$100,000 to develop CAVE technology for a number of manufacturing-related projects, including plant design. The initial work was so encouraging, says Dr. Prashant Banerjee, associate professor of mechanical engineering and director of the Virtual Reality Telecollaborative Integrated Manufacturing Environment, that the National Institute of Standards and

Technology awarded Searle and the university a three-year, \$1.65 million grant to develop a CAVE network so that engineers around the world could collaborate to design manufacturing operations and processes.

Searle representatives believe virtual reality technology will transform the way the pharmaceutical industry designs and builds new facilities. They estimate that CAVE systems could save the manufacturing industry \$735 million a year.

A CAVE network such as the one Searle wants to develop, linked by a high-speed broadband network, has stunning applications for manufacturing, says Banerjee. If a Searle engineer in Moscow happens to notice a design problem in a factory under construction there and wants to work it out with a design engineer in Chicago, they can meet in virtual reality. The engineer in Illinois will walk into the CAVE where the image of the factory is projected. The engineer in Moscow can view the same 3-D image on her Immersadesk, a smaller device developed by EVL

researchers that resembles a tilted drafting table. Instruments on her head and hand will project a computer image of her face and gestures into the CAVE in Chicago. While the Windy City engineer walks among the simulated factory's pipes and equipment, he watches his counterpart point out the problems and examines them with her.

Scientists in about 50 research centers around the globe are already using CAVEs to study hearts, enzymes, and molecules in action; analyze weather hazards; build virtual cities; and design and test cars. So far, however, U.S. manufacturers (unlike their European and Japanese counterparts) have been slow to take advantage of CAVE technology. Searle managers hope that the networking technology developed under the NIST grant will spur more American companies to begin doing some virtual spelunking themselves.

—JANE STEVENS

## VIRTUAL REALITY 2

### Practice Makes Perfect

The surgeon studies the face of a teenage boy whose upper jaw and cheek were destroyed by cancer years ago. Lifting his gloved right hand, he points to an area just below one of the patient's eyes. As if by magic, an incision appears in the boy's cheek, revealing the area of tissue and bone to be rebuilt. Pointing again, the surgeon begins a complicated procedure for transplanting bone and tissue from the boy's hip to his face.

In the past, plastic surgeons had to be in the operating room to try procedures like these. Now some are using an experimental computer visualization tool called the Immersive Workbench, developed by researchers from Stanford University and NASA Ames Research Center, to plan and practice difficult operations. The software program combines data from CT scans, magnetic res-

onance images, and ultrasound to create high-resolution pictures of individual patients and display them in a virtual environment. Unlike other software tools developed to visualize the results of plastic surgery, which rely on standard physical models of men and women, the Immersive Workbench generates images that depict the specific deformities or injuries of particular patients. The latest prototype of the software goes further, letting doctors wearing tracked-shutter glasses and special gloves test specific surgical approaches in rapid succession to see which produces the best results.

"The whole idea is to be able to interact with the virtual environment in the same way as you interact with a patient in real life—in a way that requires almost no training for the user," says project director Dr. Michael Stephanides of Stanford University's Division of Plastic Surgery.

The project started in 1991, when

## COVER YOUR ASSETS

Whether you're a CEO, R&D Director, VP of Marketing or VP of Engineering, your worst fear is not getting your product design or market approach right, before it goes out the door. At EvaluTech, our staff is trained to look at your needs differently than any other company. We help with items such as:

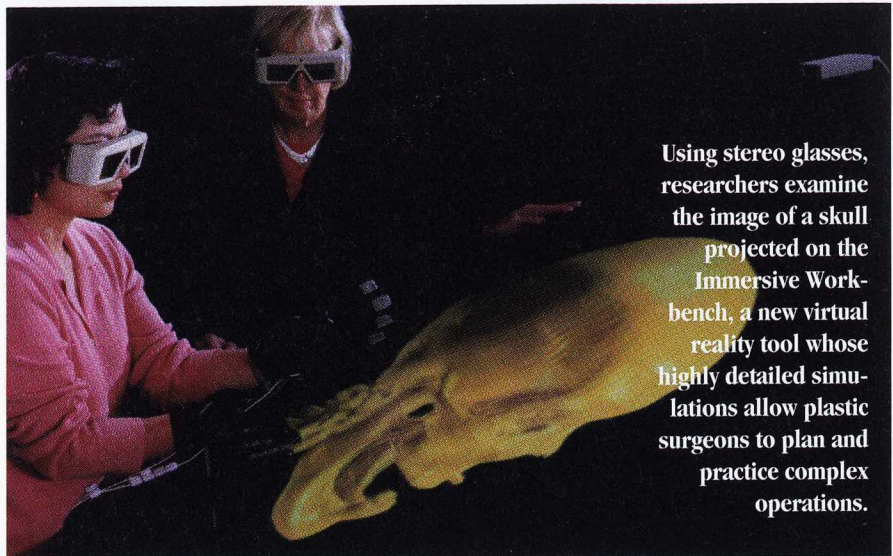
- Expert technical second opinion in evaluating new products and technologies
- Assessing competitive threats by obtaining the information you need to know, not what they want you to know
- Cost-efficient and rapid response to all aspects of technology and marketing
- Intellectual property protection strategies
- Assistance in identifying and negotiating with potential national and international licensees



**EVALUTECH**

Technology Evaluation & Commercialization

130 Bellevue Avenue Newport, RI 02840-3283  
P. 401.842.0096 F. 401.842.6997 [www.evalutech.com](http://www.evalutech.com)



Using stereo glasses, researchers examine the image of a skull projected on the Immersive Workbench, a new virtual reality tool whose highly detailed simulations allow plastic surgeons to plan and practice complex operations.

Stanford researchers began developing two-dimensional graphic renderings of patients from imaging data. Three years ago, Stephanides asked NASA Ames to create sophisticated software for building three-dimensional patient portraits from data collected in CT scans. At that time, NASA Ames engineers were spending most of their time creating visualizations of biological systems for space-related applications, but the lab's collaboration with Stanford has led to the creation of NASA Ames's Biocomputation Center, a new national center for research in virtual environments for surgical planning.

Plastic surgery offers a particularly rigorous challenge for software engineers and medical researchers developing virtual reality (VR) tools, since computerized renderings of patients must look almost exactly as they do in the real world. It is no small task to display human body parts at the necessary high resolution, says Kevin Montgomery, the leader of the NASA Ames group participating in this project. According to Montgomery, a 3D rendering of a human face and head contains 8 million tiny image slices that must be updated at a speed of 10 frames per second—processing demands that approach the theoretical limit of current computers; as a result, the NASA Ames researchers had to find ingenious ways to discard much of

the raw data from patient images. Nonetheless, Montgomery's group has been able to generate highly resolved images detailing such subtle features as small ridges of tissue, the impression of a vein beneath the skin on a human scalp, and the fine detail of a patient's inner ear.

Doctors have already used the Immersive Workbench to plan some 15 surgeries involving reconstruction of bony defects in the skeleton of the face and skull. But Montgomery and Stephanides caution that the tool is still in the experimental stage. They expect clinical deployment in three to five years, when the next generation of processors and graphics cards makes \$10,000 desktop computers as fast and powerful as the \$100,000 graphical workstations now needed to run the software. Between now and then, the researchers hope to improve the program by creating a more intuitive graphical user interface, depicting virtual surgical instruments more accurately, and developing the capacity to update patient images in near-real time as doctors practice their procedures.

When hardware costs are no longer a limiting factor, Stephanides believes VR technology will replace current surgical planning methods and become an important tool for educating doctors in medical schools.

—MARK HODGES

## MASS TRANSIT

## Monorail: Back to the Future

Remember monorail? That Jetson-era relic, one step above an amusement-park ride, zipping around airports, hotels, and, yes, amusement parks? For a brief moment in the 1960s, monorail—cars or trains running on or under a single, elevated guide rail—looked like the future of mass transit. But that bright vision was eclipsed by a surge of highway building and, more recently, the rush to build urban light-rail systems. Monorail was written off as a novelty, fine for Disneyland but hardly a serious option.

But yesterday's dreams are today's leaps forward. Thanks partly to technological improvements, partly to new recognition of the limitations of conventional rail, and especially to the grass-roots activism of impatient citizens, monorail is making a comeback. Today, space-short Japan leads the world in elevated transit, with eight urban monorails. Sydney, Vancouver, and Singapore all use monorails, as do planned communities in Brazil and parks in South Korea. Now monorail boosters in several U.S. cities are vying to make their towns next on the list.

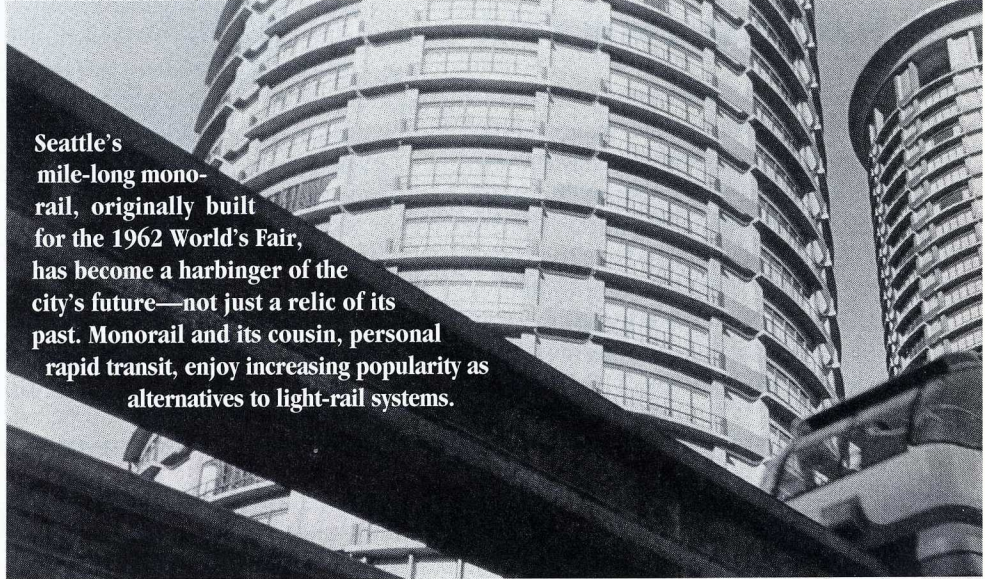
In Salt Lake City, those boosters recently attempted to persuade transit officials to build a monorail in place of a controversial planned light-rail system, on the grounds that light rail would eat up too many precious street lanes. That effort failed, but monorail boosters have made more headway with the Ohio-Kentucky-Indiana Regional Council, which has proposed a new light-rail system for the Cincinnati metropolitan area. Vexed because light-rail vehicles can't handle the grade to the regional airport on their side of the Ohio River, residents of Covington, Kentucky, are pressing for a switch to monorail, whose rubber tires and enclosed guideways provide better traction than steel-wheeled light-rail vehicles. They've persuaded their congressman, Jim Bunning,

to arrange federal funding to study the monorail option.

But it's Seattle, home to the mile-long monorail left from the 1962 World's Fair, that has given the technology its broadest endorsement. Last November, Seattle voters approved a 42-mile monorail system running to all four corners of the city, over the opposition of city officials and the business establishment, who favored light rail and buses. The ballot measure was an unusual exercise in do-it-yourself transit plan-

ans, they can be automated, eliminating the driver salaries that are conventional transit's biggest operating expense. (The other way to get trains out of traffic's way, digging tunnels, is prohibitively expensive—as Los Angeles is discovering.)

Though view-sensitive residents squirm at the thought of a monorail's elevated guideways blocking their light, today's guideways are much thinner than 1962's concrete behemoths. And their pillars are spaced more widely—



**Seattle's mile-long monorail, originally built for the 1962 World's Fair, has become a harbinger of the city's future—not just a relic of its past. Monorail and its cousin, personal rapid transit, enjoy increasing popularity as alternatives to light-rail systems.**

ning, drafted and promoted by an activist/cab driver, Dick Falkenbury, who says he got the idea while “stuck in traffic, watching the monorail zip by overhead.”

“Until you get out of traffic, you’re still stuck in traffic,” Falkenbury explains. “Once you realize that, only monorail makes sense.” The fact that most U.S. monorails are at theme parks and other private venues only proves the technology’s efficiency, he insists: “When you build with other people’s [i.e., public] money, you build light rail. When you build with your own money, you build a monorail.”

Even monorail’s critics concede that, because it weighs less, it can be elevated less expensively than rail. Elevated systems can be built quickly; because they needn’t tango with traffic and pedestri-

100-plus feet apart in a leading model from Montreal-based monorail maker Bombardier. Technical improvements have also obviated another longtime monorail shortcoming: awkward switching from one track to another. Bombardier can now switch tracks in 8 to 12 seconds, making multi-track systems feasible.

But why stop with a conventional, mass-transit monorail? University of Washington engineering professor emeritus Jerry Schneider notes that Seattle’s Monorail Initiative would allow the city to implement a truly revolutionary solution: personal rapid transit (PRT). Developed in the 1970s and now being revived on three continents, PRT offers individualized, point-to-point service in private (say, four-seater) cars running on lightweight, computer-con-

trolled, elevated guideways—usually monorails but sometimes dual rails. Variouslly dubbed “automated taxis,” “horizontal elevator,” or “personal monorail,” it’s the only transit form that just might match the automobile’s convenience, without its environmental downside.

The monorail of the future may surprise even its present-day proponents.

—ERIC SCIGLIANO

## MATERIALS

### Waxing Hot and Cold

Phase-change materials keep astronauts warm in the black void of space and cool in the solar glare. Microencapsulation is the bane of scent-sensitive magazine readers. Now two companies—Outlast Technologies, based in Boulder, Colo., and Frisby Technologies, based in Freeport, N.Y.—have married these technologies to create new kinds of clothing that regulate the wearer’s body heat.

Phase-change materials store or release heat as they oscillate between solid and liquid form. As a phase-change material changes to a solid state, it gives off heat; as it returns to a liquid state, it absorbs it—like a melting ice cube drawing the heat from a glass of water. In fact, water can be defined as a phase-change material with a trigger temperature of 32 degrees Fahrenheit. Such materials are common; one NASA study identified more than 100.

Adapting technology initially developed for the U.S. space program, the two companies are using microencapsulation—tiny capsules like those enclosing drops of fragrance in glossy magazine perfume ads—to capture the insulating properties of phase-change materials.

“Every other insulation out there depends on one thing: trapped air,” says Matt Maguire, director of technical development at Frisby. “We actually harness your body’s heat. We can trap it and use it when your body needs it.”

Not only do the microcapsules absorb more heat than traditional insu-

lations, but they also release it gradually within a specific temperature range. Rick Wolf, president of Outlast’s apparel and textile division, likens the technology to the dimmer on a light switch. “What we provide is not just insulation but temperature regulation,” he says.

A snowboard glove made with one kind of microencapsulated phase-change material, for example, has a trigger temperature of 83 degrees Fahrenheit. When a snowboarder first puts on the glove, her body heat charges the phase-change material, changing it from a solid state to a liquid. As she rides up the chair lift, the material acts as a thermal barrier, releasing heat as the microcapsules change state.

“The cold will have to turn them to solid before it can penetrate to the hands,” Maguire says.

As the snowboarder rides downhill, she generates body heat that recharges the microcapsules and begins the cycle over again.

Although the companies have licensed

# MASSACHUSETTS INSTITUTE OF TECHNOLOGY SUMMER PROFESSIONAL PROGRAM MANAGEMENT OF RESEARCH, DEVELOPMENT AND TECHNOLOGY-BASED INNOVATION

June 8 - June 19, 1998

The program is under the direction of Edward B. Roberts,  
the David Sarnoff Professor of the Management of Technology at MIT.

For further information contact:

MIT Professional Institute, 8-201, Cambridge, MA 02139

Phone 617-253-2101 • Fax 617-253-8042

E-mail: [professional-institute@mit.edu](mailto:professional-institute@mit.edu)

World Wide Web Home Page: <http://web.mit.edu/professional/summer/>

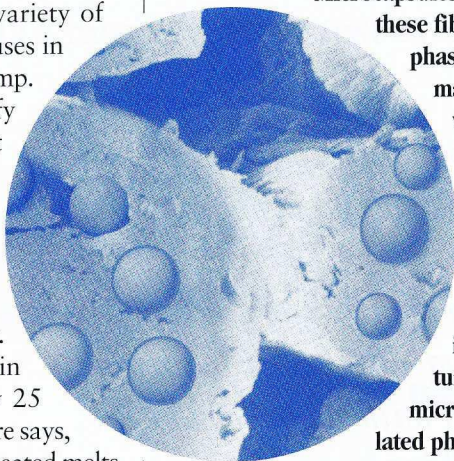
the same basic technology, they are commercializing it in different ways. Outlast has developed a proprietary process by which it embeds the microcapsules in strands of acrylic fibers or bonds a layer of them to a fabric. Frisby suspends the capsules in liquids and a variety of foams. It calls the foam it uses in apparel products ComforTemp.

Wolf declines to identify the materials in Outlast products, but Maguire says Frisby uses paraffinic materials that can be formulated with trigger temperatures that range from -30 degrees to 270 degrees Fahrenheit. The materials are housed in capsules that are typically 25 microns in diameter, Maguire says, and they "can withstand repeated melts and freezes at the same temperature almost forever."

Unlike perfume ads, whose capsules are designed to release fragrance by rupturing, Outlast and Frisby use capsules that can stand up to hard use and

repeated laundering. They are not affected by dampness, nor do they lose their effectiveness, as lofted insulations do, when the material is compressed.

Consumers are already reaping the



**Microcapsules embedded in these fibers contain phase-change materials, which change from liquid to solid in response to changes in temperature. Clothing manufacturers are using microencapsulated phase-change materials to insulate outdoor apparel and sports gear.**

benefits of this new technology. Eddie Bauer, the retail chain and apparel maker, uses Outlast in its EBTek line of

outdoor gear. Nordica will use Outlast in the liners of its top-of-the-line ski boots. Glove maker Wells Lamont uses ComforTemp foam in its Hotfingers line of ski and snowboard gloves, while competitors Grandoe and Manzella incorporate Outlast fibers and fabrics in their products. The new materials also are appearing in mountaineering boots, fishing waders, and thermal underwear. And the U.S. military is investigating ways to use them to keep soldiers and divers comfortable in severe weather.

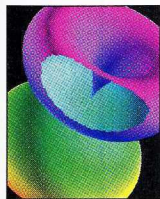
The two companies are now exploring more specialized applications for the new materials, from firefighters' suits and race car drivers' boots to cooling systems for computers and delivery containers that keep takeout food warm or blood vials cool. Frisby is even trying to create a heat-resistant coating for the underbelly of a vertical-takeoff aircraft, which could significantly reduce the vehicle's cost.

"The limits are almost boundless in terms of markets for these products," Maguire says.

—DOUG MCCLELLAN



## The Ultimate in Math Software. The Minimum in Time and Cost.



Math software reviewers consistently rank **Macsyma®** the friendliest of the powerful math software packages. Now, the improved on-line help system in new Macsyma® 2.3 contains

- smarter natural language query
- 50% more math tips
- over 100 new template buttons

to make Macsyma 2.3 friendlier than ever. Plus Macsyma 2.3 offers exciting improvements in math and graphics. Try Macsyma 2.3 at these **special reduced prices** through June 30, 1998. Macsyma's price, power, and friendliness are simply unmatched.

<b>PC Macsyma Lite</b> (limited capabilities, limited manuals)	<b>\$69</b>
<b>PC Macsyma 2.3</b> (limited manuals)	<b>\$199</b>
<b>PC Macsyma 2.3</b> (full manuals)	<b>\$249</b>
<b>PC Macsyma 2.3 Pro</b> (NumKit™, full manuals)	<b>\$349</b>
<b>UNIX Macsyma</b>	<b>\$499</b>

**PDEase2D™** finite element analysis software saves you time and effort by automatically generating and refining grids, and analyzing errors. You can solve a wide range of problems in heat transfer, solid and fluid mechanics, reaction diffusion, and electromagnetics, including nonlinear static, dynamic, and eigenvalue problems. PDEase2D shares scientific notebooks with Macsyma and imports .dxf files from leading CAD programs.



<b>PDEase2D Lite</b> (limited capabilities)	<b>\$99</b>
<b>PDEase2D Pro</b>	<b>\$999</b>

**Save on a Macsyma/PDEase bundle.**

Call **1-800-Macsyma** (1-800-622-7962) for a **free** demo CD  
or visit us at <http://www.macsyma.com>



Macsyma Inc.  
20 Academy Street  
Arlington, MA 02174-6436

tel: 781-646-4550  
fax: 781-646-3161  
email: [info@macsyma.com](mailto:info@macsyma.com)



Macsyma and PDEase are registered trademarks of Macsyma Inc. PDEase2D and NumKit are trademarks of Macsyma Inc.

## *MARS & CO*

- *we are a strategy consulting firm serving top management of leading corporations;*
- *since our inception in 1979, we have chosen to work for a limited number of leading international firms with whom we build long-term relationships;*
- *we apply fact-based, quantitative analysis to competitive problems and get involved in the implementation of our recommendations;*
- *we develop consultants with cross-industry and cross-functional experience;*
- *we promote from within;*
- *we are looking for well-balanced recent graduates with exceptional and demonstrable quantitative abilities and language skills to join at an entry level;*
- *if you wish to join our team, please send your résumé to francine even at "mars plaza"  
124 mason street, greenwich, connecticut 06830.*

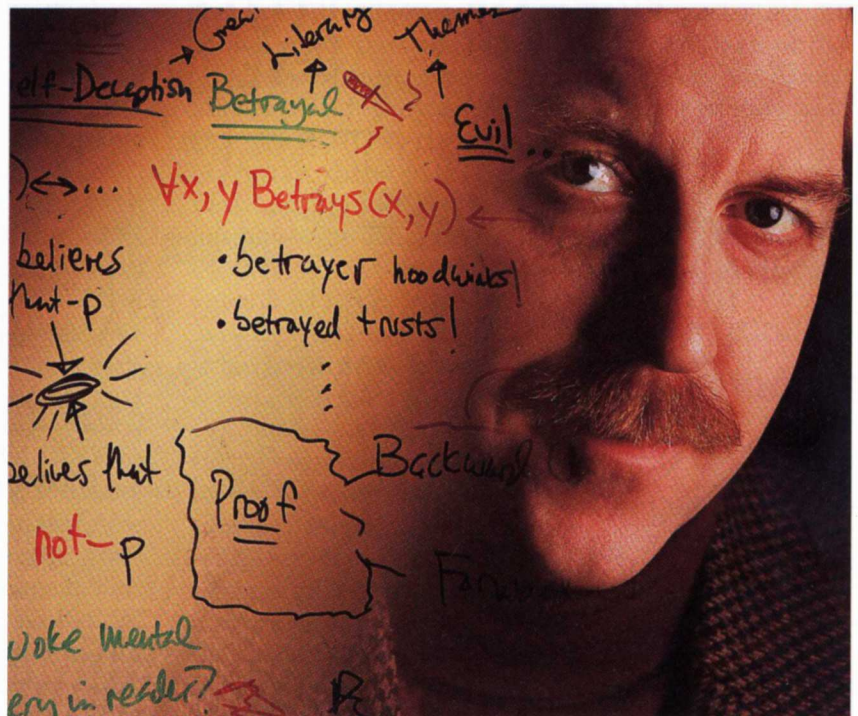
**Deep Blue's** victory over Gary Kasparov may have been entertaining, but **contrary** to popular belief, it tells us nothing about the future of artificial **intelligence**. What's needed is a more creative test of **mind** versus machine.

# Chess Is Too Easy

BY SELMER BRINGSJORD

COMPUTER science is of two minds about artificial intelligence (AI). Some computer scientists believe in so-called “Strong” AI, which holds that all human thought is completely algorithmic, that is, it can be broken down into a series

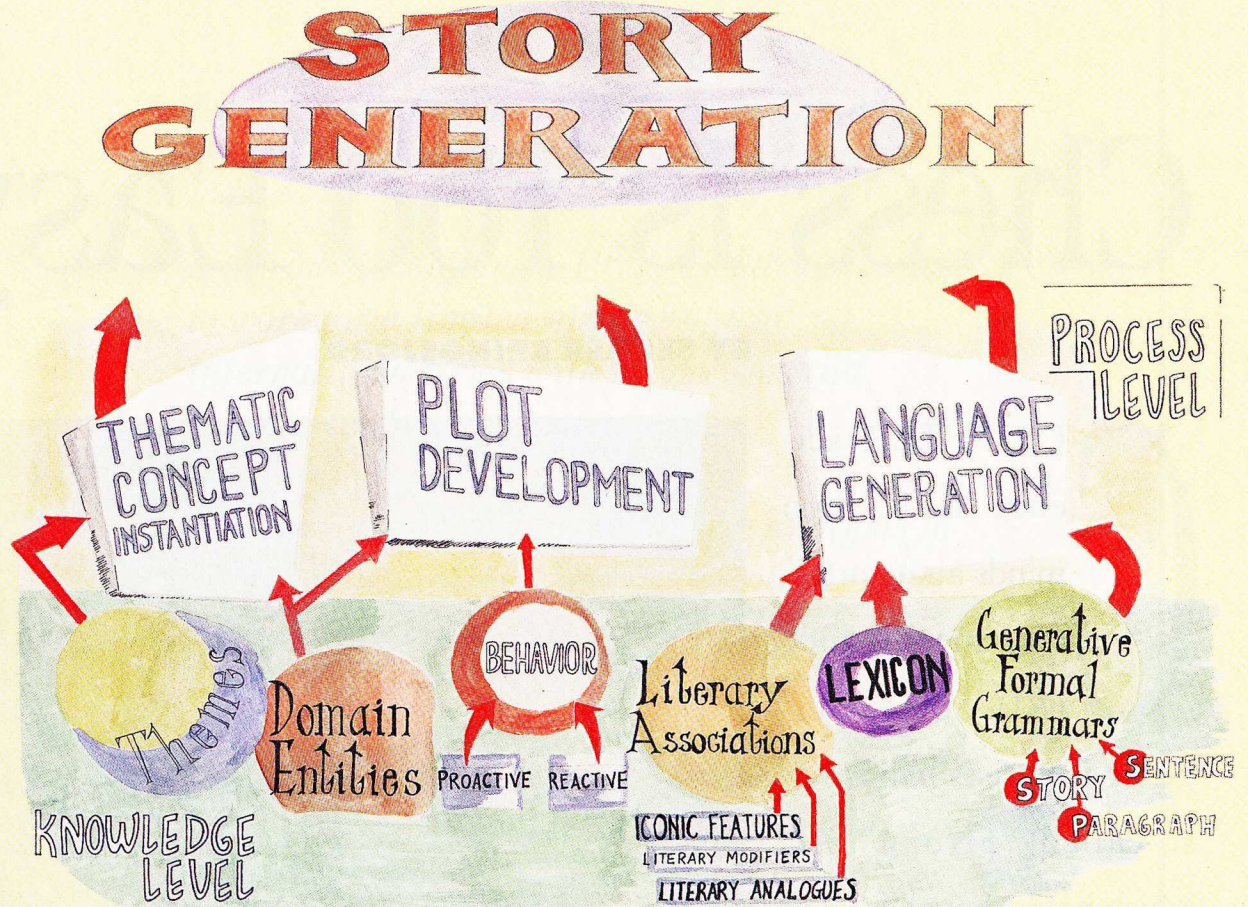
of mathematical operations. What logically follows, they contend, is that AI engineers will eventually replicate the human mind and create a genuinely self-conscious robot replete with feelings and emotions. Others embrace “Weak” AI, the notion that human thought can only be simulated in a computational



Above, the author's sketch diagrams the logic of a literary device.

# BRUTUS. 1's SYSTEM ARCHITECTURE

*Inside the Mind of a Storytelling Machine*



device. If they are right, future robots may exhibit much of the behavior of persons, but none of these robots will ever be a person; their inner life will be as empty as a rock's.

Past predictions by advocates of Strong and Weak AI have done little to move the debate forward. For example, Herbert Simon, professor of psychology at Carnegie Mellon

*SELMER BRINGSJORD is an associate professor at Rensselaer Polytechnic Institute. He teaches logic and AI in both the Department of Philosophy, Psychology & Cognitive Science and the Department of Computer Science. He is also director of RPI's Minds and Machines Program and Mind-Machine Laboratory. Further information about the issues covered in this piece, and many others related to logic, AI, and the mind, can be found on his web site: <http://www.rpi.edu/~brings>. His book *What Robots Can and Can't Be* is a sustained argument for Weak over Strong AI.*

University, perhaps the first and most vigorous adherent of Strong AI, predicted four decades ago that machines with minds were imminent. "It is not my aim to surprise or shock you," he said. "But the simplest way I can summarize is to say that there are now in the world machines that think, that learn and create. Moreover, their ability to do these things is going to increase rapidly until—in a visible future—the range of problems they can handle will be coextensive with the range to which the human mind has been applied."

On the other side of the equation, Hubert Dreyfus, a philosophy professor at Berkeley, bet the farm two decades ago that symbol-crunching computers would never even approach the problem-solving abilities of human beings, let

To create a story, BRUTUS.1—a storytelling computer seven years in the making—follows a convoluted parallel path from the bottom left of the diagram opposite. Once a user specifies certain themes, people, places, things, and behaviors, BRUTUS.1 adds “knowledge” that it has been given about literary devices, iconic features (specific words that spark mental imagery in a reader’s mind), and grammar. All of this information then flows in parallel to the “process level,” where three artificial intelligence programs, again in parallel, develop the story’s theme, plot, and prose.

to Strong AI are overlooking one important fact: from a purely logical perspective chess is remarkably easy. Indeed, as has long been known, invincible chess can theoretically be played by a mindless system, as long as it follows an algorithm that traces out the consequences of each possible move until either a mate or draw position is found.

Of course, while this algorithm is painfully simple (undergraduates in computer science routinely learn it), it is computationally complex. In fact, if we assume an average of about 32 options per play, this yields a thousand options for each full move (a move is a play by one side followed by a play in response). Hence, looking ahead five moves yields a quadrillion ( $10^{15}$ ) possibilities. Looking ahead 40 moves,

alone an inner life. In his book, *What Computers Can’t Do* (HarperCollins 1978), and again in the revised edition, *What Computers Still Can’t Do* (MIT Press 1992), he claimed that formidable chess-playing computers would remain forever in the realm of fiction, and dared the AI community to prove him wrong.

The victory last spring by IBM’s Deep Blue computer over the world’s greatest human chess player, Gary Kasparov, obliterated Dreyfus’s prediction. But does it also argue for Strong rather than Weak AI? Kasparov himself seems to think so. To the delight of Strong AI supporters, Kasparov declared in *Time* last March that he “sensed a new kind of intelligence” fighting against him.

Moreover, the well-known philosopher Daniel Dennett of Tufts University would not find such a reaction hyperbolic in light of Deep Blue’s triumph. Ever the arch-defender of Strong AI, Dennett believes that consciousness is at its core algorithmic, and that AI is rapidly reducing consciousness to computation.

But in their exultation, Kasparov, Dennett, and others who believe that Deep Blue lends credence

the length of a typical game, would involve  $10^{120}$  possibilities. Deep Blue, which examines more than 100 million positions per second, would take nearly  $10^{112}$  seconds, or about  $10^{104}$  years to examine every move. By comparison, there have been fewer than  $10^{18}$  seconds since the beginning of the universe, and the consensus among computer-chess cognoscenti is that our sun will expire before even tomorrow’s supercomputers can carry out such an exhaustive search.

But what if a computer can look very far ahead (powered, say, by the algorithm known as alpha-beta minimax search, Deep Blue’s main strategy), as opposed to all the way? And what if it could combine this processing horsepower with a pinch of knowledge of some basic principles of chess—for example, those involving king safety, which, incidentally, were installed in Deep Blue just before its match with Kasparov? The answer, as Deep Blue resoundingly showed, is that a machine so armed can best even the very best human chess player.

## CREATIVITY EX MACHINA?

But the kind of thinking that goes into chess, stacked against the full power and range of the human mind, is far from the whole story. Nineteenth century mathematician Ada Byron, known as Lady Lovelace, was perhaps the first to suggest that creativity is the essential difference between mind and machine—the defining essence that goes beyond what even the most sophisticated algorithm can accomplish. Lovelace argued that computing machines, such as that contrived by her contemporary, Charles Babbage, can’t create anything, for creation requires, minimally, originating something. Computers can originate nothing; they can merely do that which we order them, via programs, to do.

A century later Alan Turing, the grandfather of both AI and computer science, responded to Lady Lovelace’s objection by inventing the now-famous Turing Test, which a computer passes if it can fool a human into thinking that it is a human. Unfortunately, while chess is too easy, the Turing Test is still far too difficult for today’s computers. For example, deception—which a potent computer player in the Turing Test should

As has long been known, invincible chess can theoretically be played by a mindless system, as long as it follows a simple algorithm—routinely learned by computer science undergraduates—that traces out the consequences of each possible move until either a mate or draw position is found.

# Betrayal

**D**AVE Striver loved the university. He loved its ivy-covered clock towers, its ancient and sturdy brick, and its sun-splashed verdant greens and eager youth. He also loved the fact that the university is free of the stark unforgiving trials of the business world—only this isn't a fact: academia has its own tests, and some are as merciless as any in the marketplace. A prime example is the dissertation defense: to earn the PhD, to become a doctor, one must pass an oral examination on one's dissertation. This was a test Professor Edward Hart enjoyed giving.

Dave wanted desperately to be a doctor. But he needed the signatures of three people on the first page of his dissertation, the priceless inscriptions which, together, would certify that he had passed his defense. One of the signatures had to come from Professor Hart, and Hart had often said—to others and to himself—that he was honored to help Dave secure his well-earned dream.

BY BRUTUS.1

Well before the defense, Striver gave Hart a penultimate copy of his thesis. Hart read it and told Dave that it was absolutely first-rate, and that he would gladly sign it at the defense. They even shook hands in Hart's book-lined office. Dave noticed that Hart's eyes were bright and trustful, and his bearing paternal.

At the defense, Dave thought that he eloquently summarized chapter three of his dissertation. There were two questions, one from Professor Rodman and one from Dr. Teer; Dave answered both, apparently to everyone's satisfaction. There were no further objections.

Professor Rodman signed. He slid the tome to Teer; she too signed, and then slid it in front of Hart. Hart didn't move.

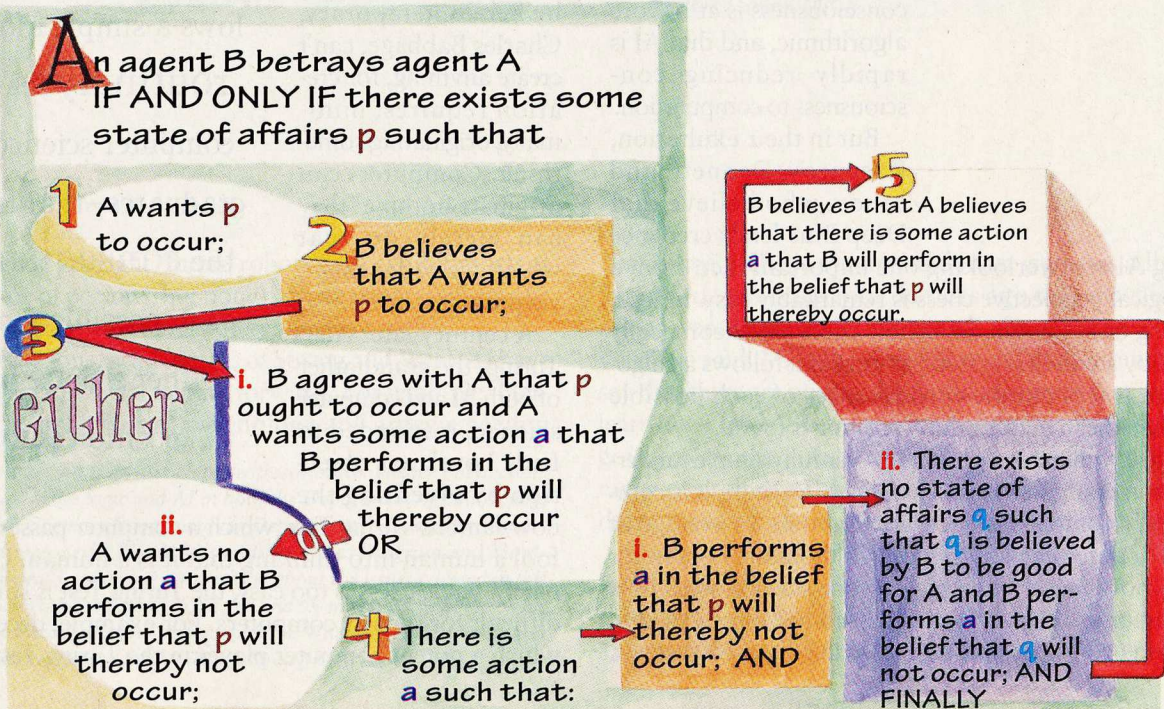
"Ed?" Rodman said.

Hart still sat motionless. Dave felt slightly dizzy. "Edward, are you going to sign?"

Later, Hart sat alone in his office, in his big leather chair, saddened by Dave's failure. He tried to think of ways he could help Dave achieve his dream.

## THE MATHEMATIZATION OF BETRAYAL

**T**O enable Brutus.1 to write the short short story "Betrayal," David Ferrucci and I devised a mathematical definition of the concept of betrayal and programmed it into Brutus.1 using Prolog and a logic-programming language called Flex. We also gave Brutus.1 knowledge of "story grammars," essentially time-honored plot structures that all good authors know by heart, and "literary grammars," which attempt to capture the logical structure and sound of creative prose. While the exact specification of the betrayal as it is represented in Brutus.1 is too esoteric to reproduce here, we can give you a sense of what these specifications are, based on the logic statements illustrated below.



surely be capable of—is an incredibly complex concept. To urge a person to mistakenly accept a false notion requires that the computer understand not only that the idea is false, but also the myriad subtle connections that exist between the idea and that person's beliefs, attitudes, and countless other ideas.

Though the Turing Test is currently out of the reach of the smartest of our machines, there may be a simpler way of deciding between the strong and weak forms of AI—one that highlights creativity, which may well be the real issue in the Strong vs. Weak clash. The test I propose is simply: Can a machine tell a story?

Although the virtue of this test might not seem obvious at first glance, there are some interesting reasons for thinking that it's a good index of "mindedness." For example, the dominant test of creativity in use in psychology—Torrance Tests of Creative Thinking—request subjects to produce narratives.

Nor is the presence of narrative in these tests arbitrary; many cognitive scientists plausibly argue that narrative is at the very heart of human cognition. Roger Schank, a well-known cognitive scientist at Northwestern University, boldly asserts that "virtually all human knowledge" is based on stories. His fundamental claim is that when you remember the past, you remember it as a set of stories, and when you communicate information you also deliver it in the form of stories.

But perhaps most significant for this discussion, the story game would strike right to the heart of the distinction between Strong and Weak AI. Humans find it impossible to produce literature without adopting the points of view of characters, that is, without feeling what it's like to be these characters; hence human authors generate stories by capitalizing on the fact that they are conscious in the fullest sense of the word—which is to be conscious simultaneously of oneself, of another person, and of the relation (or lack thereof) between the two persons.

## DEEP STORY

It looks as though a "story game" would therefore be a better test of whether computers can think than the chess and checkers games that currently predominate at AI conferences. But what would the story game look like? In the story game, we would give both the computer and a master human storyteller a relatively simple sentence, say: "Gregor woke to find that his abdomen was as hard as a shell, and that where his right arm had been, there now wiggled a tentacle." Both players must then fashion a story designed to be truly interesting, the more literary in nature—in terms of rich characterization, lack of predictability, and interesting language—the better. We could then have a human judge the stories so that, as in the Turing Test, when such a judge

**Brutus.I**  
is capable of  
writing **short**  
short stories based on  
the notion of  
**betrayal**. But to  
adapt Brutus.I  
to play well in a  
short short story  
game, he would have  
to **understand**  
not only betrayal,  
but other great literary **themes** as  
well—unrequited  
love, jealousy, patri-  
cide, and so on.

cannot tell which response is coming from the mechanical muse and which is from the human, we say that the machine has won the game.

How will future machines fare in such a game? I think the length of the story is a key variable. A story game pitting mind against machine in which the length and complexity of the narrative is open-ended would certainly seal the machine's defeat for centuries to come. Though advocates of Strong AI would hold that a machine could eventually prevail in a contest to see whether mind or machine could produce a better novel, even they would agree that trying to build such a machine today is unthinkable. The task would be so hard that no one would even know where to begin.

In short, though the Turing test is, as noted, too hard to provide the format for mind-machine competition at present, many people think they can imagine a near future when a machine will hold its own in this test. When it comes to the unrestricted story game, however, such a future simply can't be conceived. We can of course imagine a future in which a computer prints out a novel—but we

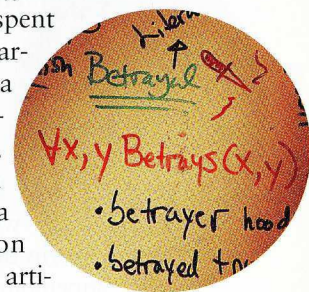
can't imagine the algorithms that would be in operation behind the scenes.

So, just to give Strong AI supporters a fighting chance, I would restrict the competition to the shortest of short stories, say, less than 500 words in length. This version of the game should prove a tempting challenge to Strong AI engineers. And, like the full version, it demands creativity from those—mind or machine—who would play it.

How then might future machines stack up against human authors when each is given that one sentence as the jumping-off point toward a short short story?

I may not be positioned badly to make predictions. With help from the Luce Foundation, Apple Computer, IBM, Rensselaer Polytechnic Institute (RPI), and the National Science Foundation, I have spent the past seven years (and about three-quarters of a million dollars) working with a number of researchers—most prominently Marie Meteer, a scientist at Bolt, Beranek and Newman; David Porush, a professor at RPI; and David Ferrucci, a senior scientist at IBM's T.J. Watson Research Center—to build a formidable artificial author of short short stories.

Part of what drives me and other researchers in the quest to create such synthetic Prousts, Joyces, and Kafkas is a belief that genuinely intelligent stand-alone entertainment systems of the future will require, among other things, AI systems that know how to create and direct stories. In the



virtual story worlds of the future, replete with artificial characters, things will unfold too quickly in real time for a human to be guiding the process. The gaming industry currently walks a fine line between rigidly prescribing a game and letting things happen willy-nilly when humans make choices. What is desperately needed is an artificial intelligence that is able to coax events into a continuous narrative thread while at the same time allowing human players to play in a seemingly infinite space of plot trajectories.

The most recent result of my toil in this regard (in collaboration with Ferrucci and Adam Lally, a software engineer with Legal Knowledge Systems of Troy, N.Y.) is an artificial agent called Brutus.1, so named because the literary concept it specializes in is betrayal. Unfortunately, Brutus.1 is not capable of playing the short short story game. It has knowledge about the ontology of academia—professors, dissertations, students, classes, and so forth; but it would be paralyzed by a question outside its knowledge base. For instance, it doesn't know anything about insect anatomy. Therefore, the sentence involving Gregor would draw a blank.

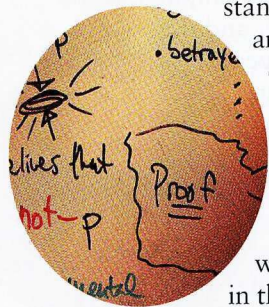
Nonetheless, Brutus.1 is capable of writing short short stories—if the stories are based on the notion of betrayal (as well as self-deception, evil, and to some extent voyeurism), which are not unpromising literary conceits (see sidebar, “Betrayal,” by Brutus.1—as well as *Richard III*, *Macbeth*, *Othello*).

Such near-belletristic feats are possible for Brutus.1 only because Ferrucci and I were able to devise a formal mathematical definition of betrayal and endow Brutus.1 with the concept (see sidebar, “The Mathematization of Betrayal”). But to adapt Brutus.1 to play well in a short short story game, it would certainly need to understand not only betrayal, but other great literary themes as well—unrequited love, revenge, jealousy, patricide, and so on.

## FOREVER UNCONSCIOUS

I have three more years to go on my ten-year project to build a formidable silicon Hemingway. At this point, however, even though Brutus.1 is impressive and even though our intention is to craft descendants of Brutus.1 that can understand a full complement of literary concepts and more, it seems pretty clear that computers will never best human storytellers in even a short short story competition.

It is clear from our work that to tell a truly compelling story, a machine would need to understand the “inner lives” of his or her characters. And to do that, it would need not only to think mechanically in the sense of swift calculation (the forte of supercomputers like Deep Blue), it would also need to think experientially in the sense of having subjective or phenomenal awareness. For example, a person can think experientially about a trip to Europe as a kid, remember what it was like to be in Paris on a sunny day with an older brother, smash a drive down a fairway, feel a lover's touch,



To tell  
a truly compelling  
story, a machine would  
need to understand  
the “inner lives” of its  
characters. And to do  
that, it would need  
not only to think  
mechanically  
in the sense of swift  
calculation, but  
experientially in  
the sense of having  
awareness.

ski on the edge, or need a good night's sleep. But any such example, I claim, will demand capabilities no machine will ever have.

Renowned human storytellers understand this concept. For example, playwright Henrik Ibsen said: “I have to have the character in mind through and through, I must penetrate into the last wrinkle of his soul.” Such a *modus operandi* is forever closed off to a machine.

Supporters of Strong AI, should they strive to build a machine that is able to prevail in the short short story game, must therefore strive to build precisely what distinguishes Strong from Weak AI: a conscious machine. Yet in

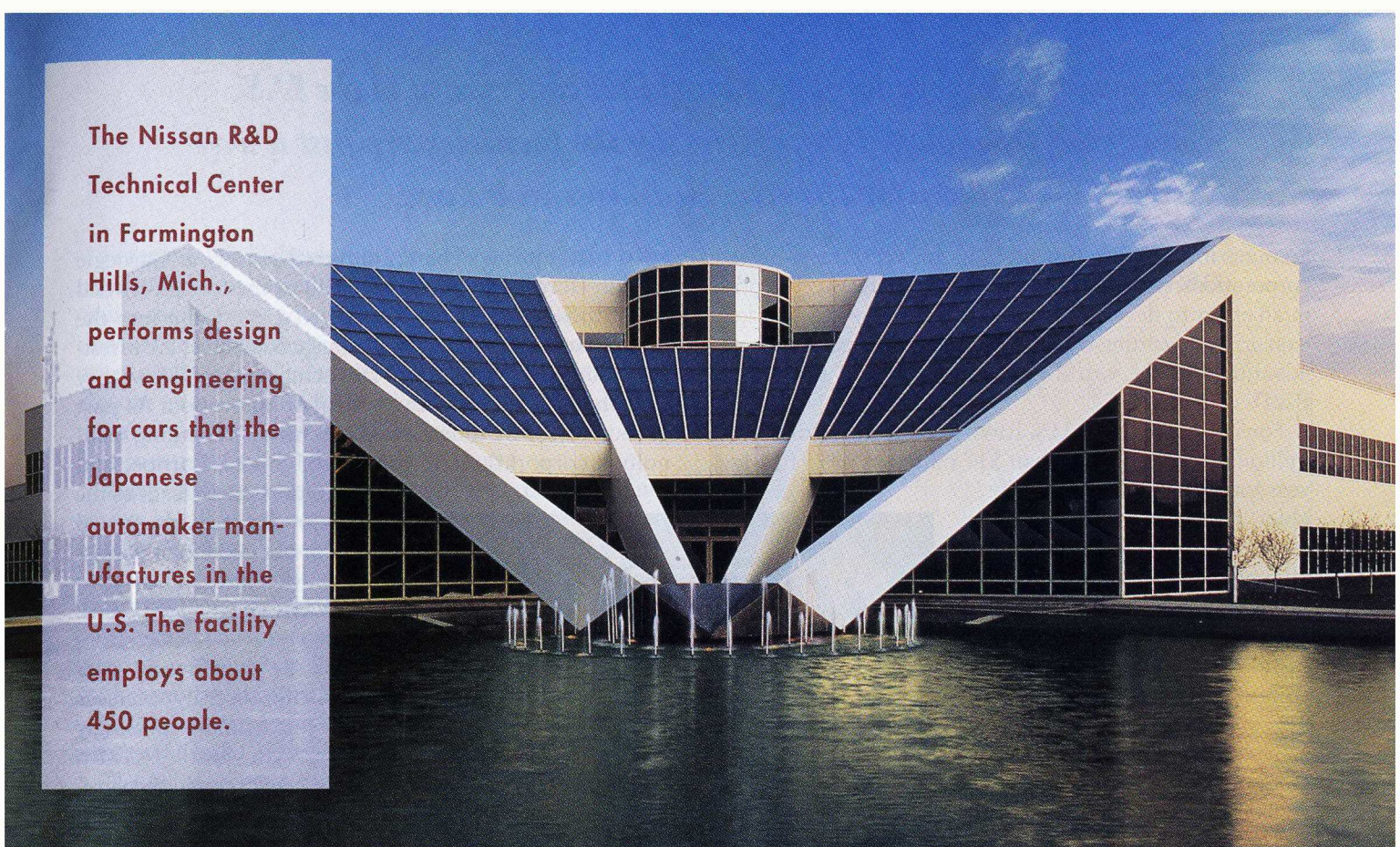
striving for such a machine, Strong AI researchers are waiting for a culmination that will forever be arriving, never present.

Believers in Weak AI, like myself, will seek to engineer systems that, lacking Ibsen's capacity to look out through the eyes of another, will create richly drawn characters. But though I expect to make headway, I expect that, unlike chess playing, first-rate storytelling, even at the humble length of short short stories, will always be the sole province of human masters.

Still, I'll continue with the last three years of my project, largely because I expect to have a lot of fun, as well as to be able to say with some authority that machines can't be creative and conscious (seeing as how I'm using state-of-the-art techniques), and to produce working systems that will have considerable scientific and economic value.

Kasparov no doubt will return soon for another round of chess with Deep Blue or its descendants, and he may well win. In fact, I suspect it will be another 10 years before machine chess players defeat grand masters in tournament after tournament. Soon enough, however, Kasparov and those who take his throne will invariably lose.

But such is not the case when we consider the chances of those who would seek to humble not only great chess players, but great authors. I don't believe that John Updike or his successors will ever find themselves in the thick of a storytelling game, sweating under lights as bright and hot as those that shone down on Gary Kasparov. ■



The Nissan R&D Technical Center in Farmington Hills, Mich., performs design and engineering for cars that the Japanese automaker manufactures in the U.S. The facility employs about 450 people.

# Other Countries' Money

BY RICHARD FLORIDA

**A**T A NEW RESEARCH complex in Palo Alto, Calif., scientists, engineers, and software developers create technologies for the knowledge-based work environment of the 21st century. At another laboratory in Kendall Square in Cambridge, Mass.—practically across the street from MIT—computer scientists, artificial intelligence experts, and software developers pioneer advanced computing and information systems. Inside a striking new facility in Princeton, N.J., Nobel Prize-winning scientists conduct basic research at the frontiers of information technology. We've all heard that U.S. companies and government agencies are slicing their R&D budgets, so what

**Foreign investment is buying U.S. R&D despite fears of technology piracy—an object lesson in the globalization of innovation.**

*Proponents believe foreign-owned labs contribute to the U.S. science and technology base; critics say the facilities are just a way to monitor the American research scene.*

accounts for these investments? The answer: foreign-owned corporations, pouring money into the U.S. R&D enterprise in an effort to develop products for the huge U.S. market, gain access to cutting-edge scientists and engineers, and take advantage of the world's most creative and productive R&D climate.

Foreign investment in U.S.-based R&D shot up from \$700 million in 1987 to more than \$17 billion in 1995 (the last year for which figures are available). The latter amount represented more than 15 percent of all funding for industrial R&D in America that year, according to a survey by the U.S. Department of Commerce. Foreign companies employ more than 100,000 Americans in R&D activities at hundreds of research laboratories and manufacturing facilities.

The growing presence of foreign companies conducting research and development in the U.S. reflects a fundamental trend: the globalization of innovation. Multinational enterprises have long operated international networks of manufacturing plants. But over the past decade, these multinationals have added a new dimension to their activities—an increasing capacity for R&D and innovation in various locations outside their home countries.

The relatively new phenomenon of foreign-owned, U.S.-based R&D has provoked controversy. Proponents believe foreign-owned laboratories contribute to the U.S. science and technology base, and that the government should encourage their development. Critics argue that the facilities are merely skeleton research operations designed to monitor the American research scene—even pirate ideas developed here.

*RICHARD FLORIDA is director of the Center for Economic Development at Carnegie Mellon University. He is completing two books: *Financiers of Innovation*, with Martin Kenney (Princeton University Press) and *For Knowledge and Profit*, with Wesley Cohen (Oxford University Press).*

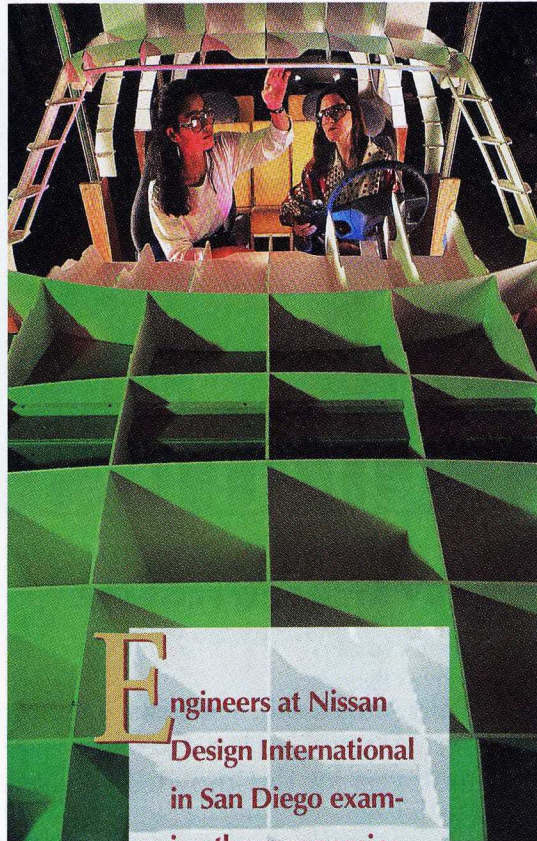
To sort out this debate, I directed a study at Carnegie Mellon University. We surveyed all of the foreign-owned laboratories in the United States to gain insight into the thorny issues surrounding why foreign companies are investing in America, what foreign labs actually do, and how they contribute to the American system of innovation. As part of the project we interviewed executives of leading technology corporations in the United States, Europe, and Japan. Our research leads to the conclusion that foreign-owned labs do more good than harm.

#### INNOVATION GOES GLOBAL

Part of the controversy over R&D bankrolled by overseas firms stems from its startlingly rapid growth. Until recently, most companies conducted virtually all of their R&D at home. The past decade, however, has seen an explosion of international R&D activities by large multinational firms.

U.S.-based enterprises invest nearly \$15 billion per year in off-shore R&D, roughly 10 percent of their total R&D budgets, according to the Department of Commerce study. In the European Community, foreign investment in R&D has increased by more than 50 percent over the past decade, now accounting for 7 percent of European R&D. IBM has long operated a network of European labs, including a Zurich facility responsible for breakthroughs in superconductivity. Japanese companies operate an extensive and growing network of more than 200 overseas laboratories.

In Japan, U.S. and European companies are establishing a growing number of personal computer and consumer electronics laboratories. Again, IBM is an important player, having operated a major research center, the IBM Japan Tokyo Research Center Laboratory, for some time. Hewlett Packard, DEC, Intel, Microsoft, Motorola, Texas Instruments, Intel, and Apple also operate research labs in Japan.



**E**ngineers at Nissan Design International in San Diego examine the ergonomics of automotive seating. Close contact with the American public led Nissan to design a movable-seat system for the Quest minivan.

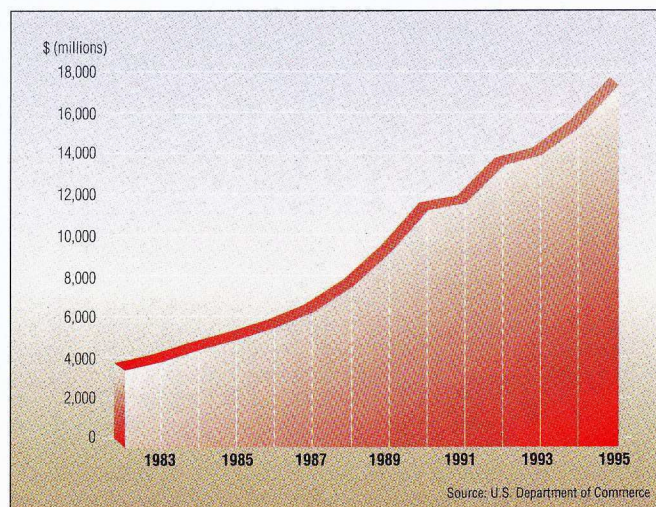
Foreign-owned laboratories are a response in part to the rapid and thoroughgoing globalization of markets—in particular the fact that goods are increasingly produced where they are sold. Off-shore factories of multinational enterprises produce \$6 trillion worth of goods and services annually, far exceeding the \$500 billion generated by international trade, according to the United Nations Division on Transnational Corporations and Investment.

These offshore investments contribute to corporate innovation by allowing companies to get close to their customers. At Nissan's automotive design studio in San Diego, for example, engineers drive the streets asking motorists what they do and don't like about their cars. Just such an on-the-road encounter with a frustrated minivan user led Nissan to design a track system for Ford's Quest minivan so that motorists can slide seats back and forth inside the vehicle when cargo space is needed, rather than having to remove the bulky seats altogether.

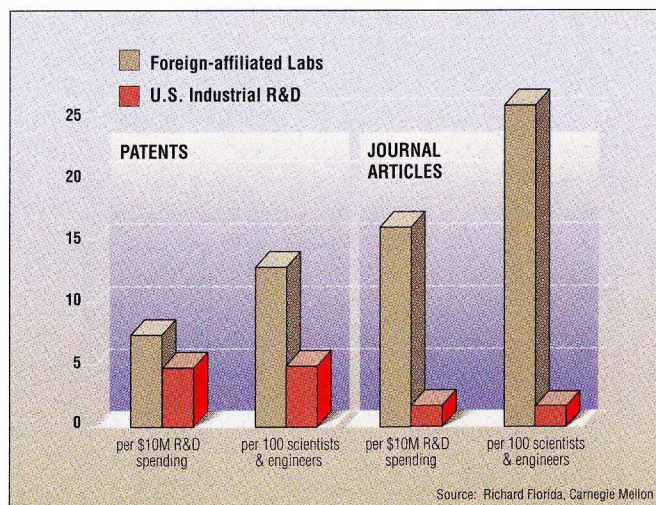
The drive to get close to the customer has been compounded by pressure from local governments, which have in many cases demanded that companies setting up factories in their countries also conduct R&D there. This pressure wouldn't mean much, however, if the countries overseas weren't capable of conducting research. But European countries, Japan, and the newly industrializing nations of Asia have made substantial investments in science and technology as part of their quest for economic growth. As a result, chief technology officers in Europe, Japan, and North America expect to rely much more heavily on technology originating from external sources in the near future, according to a recent survey by Edward Roberts of MIT's Sloan School of Management. Indeed, Joel Birnbaum, senior vice president for R&D and director of Hewlett Packard Laboratories, says his company no longer thinks of R&D along American, or even national, lines, but instead as a global system.

These massive outflows of research and development funding often involve international business alliances. To develop the competitive technologies the market demands, companies engage in joint ventures with customers, suppliers—even rivals from other countries. For example, when Nissan realized it needed bigger projects to help support its large-scale R&D facilities, the company formed an alliance with Ford to build the Nissan Quest/Ford Villager minivan. Ford made the product Nissan designed. IBM and Toshiba not only worked together to develop the flat-panel displays of the IBM Thinkpad, they also jointly manufacture them. IBM, Toshiba, and Siemens are collaborating at IBM's North American facilities to develop next generation semiconductor memory chips. Off-shore labs facilitate these partnerships by allowing companies to have scientists and technical people on the ground who can engage in such collaborations,

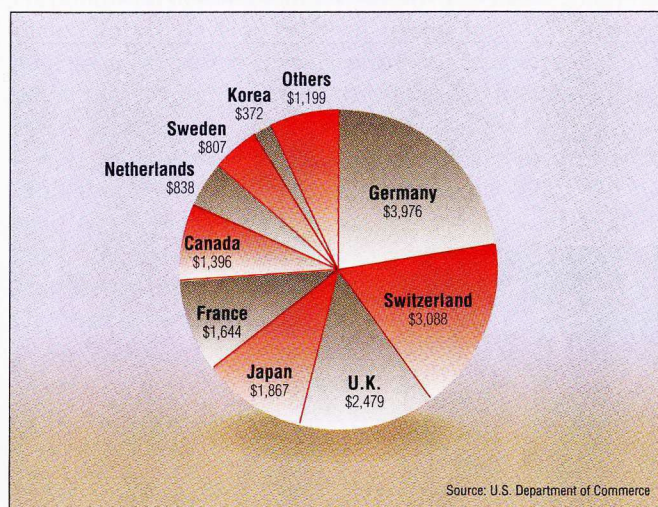
## Foreign Investment in U.S. R&D



## What Foreign Money Produces



## R&D Investment by Country (millions)



and by acting as satellite connections to sources of ideas and technology wherever they are.

## THE AMERICAN ATTRACTION

Yet if the export of research dollars is a global phenomenon, the largest share of it pours into the United States. The magnet that draws this funding is talent: Companies open labs in the United States to gain access to world-class researchers. This explains the proximity of many labs to major research universities, which they regard as a key source of commercial innovation. The NEC Research Institute, for example, was able to recruit renowned computer scientists partly because it is adjacent to Princeton University. When Canon established a research center for work on optical character recognition, image compression, and network systems, the company chose Palo Alto to be close to Stanford University and Xerox's famed Palo Alto Research Center. Mitsubishi Electric Research Laboratory, which conducts R&D on a range of information technology including computer vision, is next door to MIT.

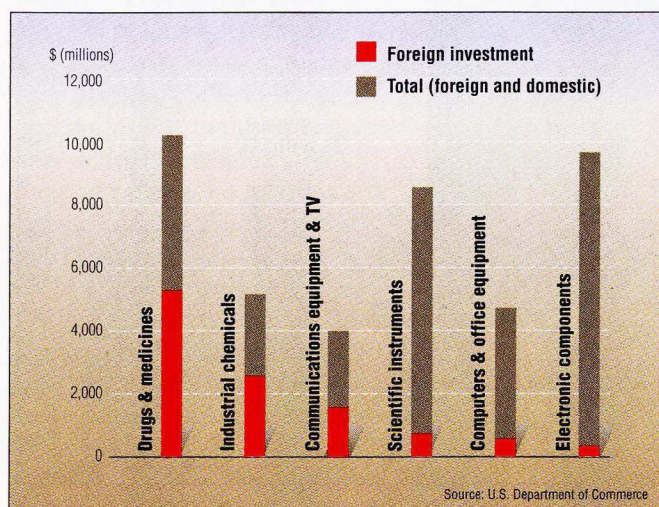
Building your new R&D facility across the street from a famous university isn't the only way to gain access. A number of foreign companies have formed agreements with leading U.S. universities and research institutes to reach their talent. Ciba-Geigy, for example, sponsors research at the University of San Diego, and the Swiss company Sandoz Pharma funds basic science at the Scripps Research Institute in San Diego. Shiseido, the Japanese cosmetics company, invested \$90 million in the Harvard Medical School for skin research.

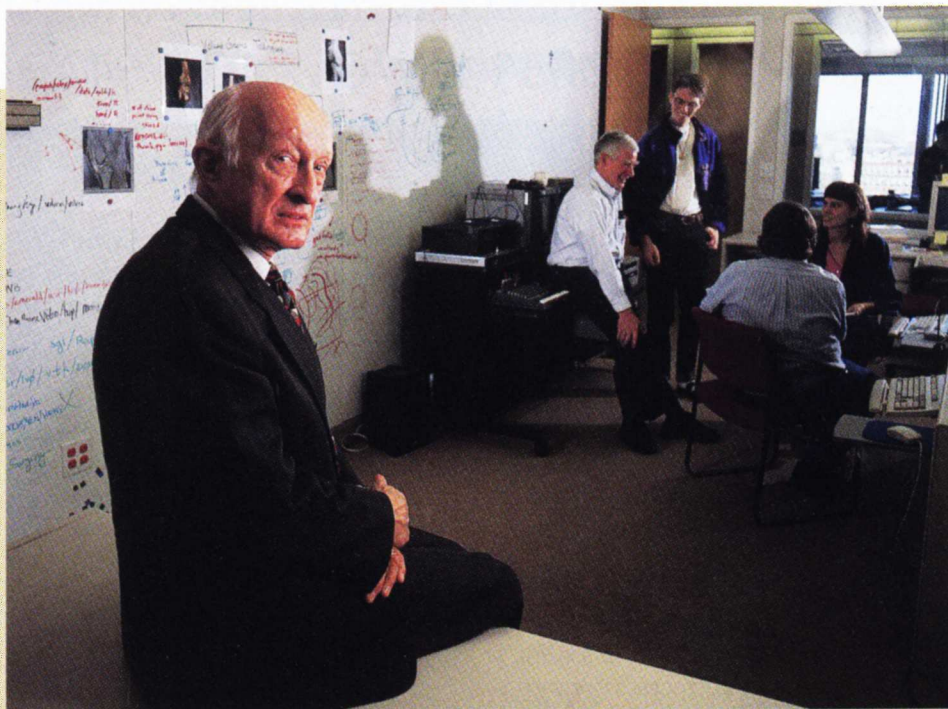
In the automotive industry, foreign laboratories gear their work to supporting U.S. manufacturing plants and customizing products for the American market. Nissan Design International's close ties to the U.S. market enabled them to realize that Nissan could attract American car buyers by adding a stylish body to a pickup truck platform. The result: the Pathfinder, which launched the sport utility craze and transformed the entire automotive market.

While the funding for these labs comes from abroad, the style of work in them is very much indigenous. Offshore companies generally recognize that to recruit and retain American researchers requires adoption of an American style of management. In this respect, these labs differ markedly from foreign-owned manufacturing facilities. Japanese companies that run U.S. factories, for example, typically seek to transfer and transplant to their U.S. facilities manufacturing practices honed at home.

As a result, foreign laboratories in America are organized much like leading research centers of American universities. These labs encourage scientific and technical staff to work autonomously and publish widely. They sponsor visiting

## R&D Investment by Sector





## LAZLO BELADY *Global Technologist*

**L**AZLO Belady personifies the globalization of R&D. He was born in Hungary and trained as an aeronautical engineer, then moved to Germany in 1956 to take up automotive engineering at Ford's European operation in Cologne. But Belady yearned to get back to his roots in advanced aviation, and in 1959 he relocated to France, working in supersonic aerodynamics for Mirage airplanes.

The real aerospace action in those days was on the other side of the Atlantic, however, and in 1961 Belady moved to the United States with his wife and infant son. As a citizen of a communist country, Belady found it almost impossible to get the security clearances required

for work in the burgeoning industry. He fell back on the computer programming skills he had honed doing supersonic calculations in France, and landed a position at IBM's new research lab. Belady earned renown there for developing insights into programming algorithms, and he went on to head a 15-person team that worked at the cutting edge of computer graphics.

IBM abandoned the project in 1971. Belady spent a year as visiting professor at the University of California at Berkeley, then returned to IBM to direct an R&D group working on maintenance of complex operating systems, a subject he wrote a book on. He later became director of software technology for the

blue-chip firm, and by the early 1980s was tapped to help launch IBM's new research center in Japan.

Retirement from IBM left Belady in search of new challenges. Rather than traveling or enjoying the comforts of his several "homes" around the globe, he took a position working with Admiral Bobby Inman at the new Microelectronics Computer Corp. in Texas. He stayed for nearly 7 years.

A second retirement in 1990 opened the door for Tohei Nitta of Mitsubishi Electric to recruit Belady as the founding director of the Mitsubishi Electric Research Laboratory (MERL) in Cambridge. Belady now heads Mitsubishi Information Technology Centers of Amer-

ica, which oversees three Mitsubishi labs in the United States—MERL, Horizon Systems Lab in Waltham, Mass., and the Advanced Television Lab in Princeton, N.J.

At first, Belady concedes, it was difficult recruiting Americans to work at MERL. "It was a time of Japan-bashing," he recalls, and many people suspected that the lab's main purpose was to "steal U.S. technology." That perception has diminished over time, he says, as word got out of the environment at MERL. "People come in and out, and we have no security badges," says Belady. "We are more open than any industrial laboratory I have ever seen in my life." ■

—RICHARD FLORIDA

*Any policies that attempt to give U.S. companies an edge over foreign ones will lead to a vicious downward spiral, in which all countries begin to impose tighter and tighter restrictions on one another.*

scholars and host seminars and symposia—practices that are unfamiliar in Japanese corporate labs. Says the manager of one foreign lab: “Everyone comes in and talks with us, and individual researchers can invite their peers for discussion.” One senior R&D manager I interviewed produced a company memorandum stating the mission as building a laboratory where scientists “do their basic research, regardless of whether or not it produces a salable product, or any product at all.”

By setting themselves up this way, companies can attract top-notch scientific and technical talent and build important connections to leading scientists and researchers at other institutions. Scientific labor markets differ from other labor markets in that they are driven to a large degree by reputation and prestige. This is why universities with leading scientists and departments are able to recruit the top new researchers and graduate students. These lessons are not lost on foreign corporations, which organize themselves like American R&D centers and universities to attract the top scientists, who in turn attract other scientists, bolstering the overall reputation of the organization.

Mitsubishi's Electric Research Laboratories, for example, organized its Cambridge Research Center so that computer scientists, artificial intelligence experts, and software developers can explore how people work with computers and modern technology. Founding president Tohei Nitta and his counterpart Lazlo Belady started the lab in part to learn about the ability of American organizations to spur innovation. “We can be much more creative over here,” Nitta says, largely because of the synergies between the lab's scientists and the rich university community of Cambridge.

Having labs in the United States also makes it easier to recruit top people back home and in other nations around the world. Michiyuki Uenohara, an executive director of NEC and founder of NEC Research Institute in Princeton, N.J., says the biggest dividend of operating the lab was that it increased the company's ability to attract the best Japanese scientific and technical talent by showcasing the organization's award-winning scientists.

## WHAT FOREIGN LABS CONTRIBUTE

But if being in the United States is clearly good for the companies that build their research facilities here, is it good for the host country as well? That question is more difficult to answer.

Critics of foreign investment in U.S. R&D see a threat to American technological leadership by giving international companies easy access to U.S. technology. According to this “technonationalist” point of view, foreign R&D facilities are skeleton operations designed to monitor and pirate

American ideas. Thus, this view holds, foreign investment in R&D in the United States should be restricted. Influential exponents of this view include Clyde V. Prestowitz, formerly of the Reagan administration's Department of Commerce and now president of the Economic Strategy Institute in Washington.

Technonationalism rests on the notion that federal policymakers can tilt the rules of innovation to benefit American companies over foreign competitors, or develop rules and regulations that reward “good” U.S. companies (those that invest in the United States) over “bad” ones (those that invest abroad). “Technoglobalists” counter that while such policy proposals are well-intentioned and seek to protect American investments, they are completely out of touch with the reality of a global system of innovation. According to this point of view, investments by foreign corporations in U.S. R&D strengthen American science and technology, especially when government and private sponsorship of U.S. research is being cut back. Any attempt to restrict foreign laboratories would therefore cut off a valuable source of R&D investment.

To sort out this issue, we must examine what exactly foreign-owned laboratories produce. Plenty, according to the Carnegie Mellon survey. These labs churn out patents at rates that exceed those of U.S. industrial R&D. Foreign labs in America generated 7.3 patents per \$10 million in R&D spending, compared with 4.7 patents per \$10 million of company-financed industrial R&D for the U.S. as a whole. In evaluating these figures, keep in mind that foreign labs tend to be engaged in a company's most patent-intensive activities. The U.S. rate of patents is lower in part because it is based on all industrial R&D, including work such as manufacturing engineering, which often leads to improvements in process technology rather than new products.

Foreign laboratories also add considerably to the stock of new scientific and technical knowledge by reporting their findings in scientific and technical journals. They publish an average of 10 journal articles per 100 scientists and engineers per year, better than the rate for industrial R&D by U.S.-owned companies. Moreover, these labs share their findings with scientists and researchers from other institutions by sponsoring seminars and workshops. One senior American researcher working in a foreign-owned laboratory says the facility is “the most open industrial laboratory I've ever worked in.”

## MAKING FOREIGN R&D INVESTMENT WORK FOR US

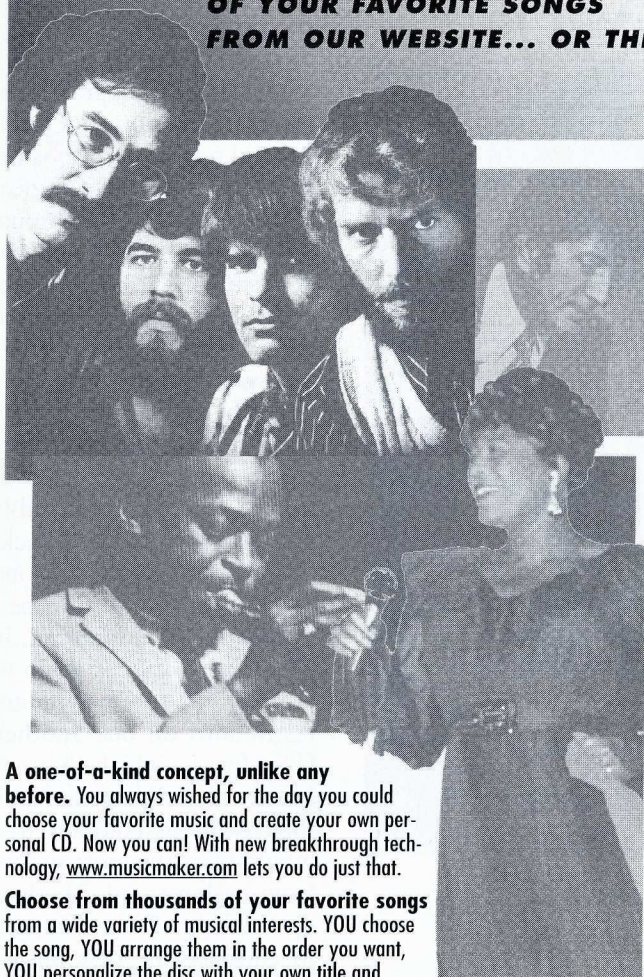
Policy-makers have long worked from the assumption that nations have self-contained and isolated science and tech-

NOW FOR THE FIRST TIME, A NEW WAY TO

# CREATE YOUR OWN PERSONAL MUSIC CDS

## www.musicmaker.com

**CHOOSE FROM  
THOUSANDS AND THOUSANDS  
OF YOUR FAVORITE SONGS  
FROM OUR WEBSITE... OR THE MUSICMAKER CATALOG.**



**Take one selection FREE  
for every 5 you choose.**

### MAKE YOUR OWN GREATEST HITS CD Creedence Clearwater Revival :

- Proud Mary .....001
- Suzie Q .....002
- Bad Moon Rising .....003
- Green River .....004
- Down on the Corner .....005
- Who'll Stop the Rain .....006
- Born on the Bayou .....007
- Fortunate Son .....008
- Travelin' Man .....009
- Lookin' Out My Back Door .....010
- Have You Ever Seen the Rain .....011
- Sweet Hitch-Hiker .....012
- Heard It Through the Grapevine .....013
- Midnight Special .....014
- Good Golly Miss Molly .....015

### Jazz Legends

- Miles Davis: My Funny Valentine .....016
- Chet Baker: How High the Moon .....017
- Sarah Vaughan: Lush Life .....018
- Stan Getz: I've Got You Under My Skin .....019
- Wes Montgomery: Round Midnight .....020
- Gene Ammons: Till There Was You .....021
- Dizzy Gillespie: Pensativo .....022
- Ella Fitzgerald: Fine And Mellow .....023
- Andre Previn: Let's Fall In Love .....024
- Charles Mingus: A Foggy Day .....025
- Vince Guaraldi: Charlie Brown Theme .....026
- Oscar Peterson: Satin Doll .....027
- MJQ: I'll Remember April .....028
- Milt Jackson: The Nearness of You .....029
- Thelonious Monk: Blue Monk .....030
- John Coltrane: Lush Life .....031
- Les Brown: Misty .....032
- Bill Evans: Waltz for Debby .....033

- Duke Ellington: Sophisticated Lady .....034
- Ron Carter: Stella By Starlight 035 .....035
- Art Blakey: Caravan .....036
- Louis Armstrong: Mack the Knife .....037
- Sonny Rollins: Way Out West .....038
- Flora Purim: Light as a Feather .....039
- Joe Pass: All The Things You Are .....040
- Lester Young: Lester Leaps In .....041
- Cannonball Adderley: Autumn Leaves .....042
- Clifford Brown: The Song Is You .....043
- Miles Davis: Round Midnight .....044
- Charlie Byrd: Desafinado .....045
- Dave Brubeck: 'S Wonderful .....046
- Art Tatum: Embraceable You .....047

### Rock, Blues & More

- Little Richard: Long Tall Sally .....048
- Jerry Garcia: Positively 4th Street .....049
- Eddie Floyd: Knock On Wood .....050
- Albert King: Sky Is Crying .....051
- Otis Redding: Dock of the Bay .....052
- Ray Charles: Georgia on my Mind .....053
- Joe Turner: Corinne, Corinna .....054
- Otis Spann: Dust My Broom .....055
- Victoria Spivey: Let's Ride Tonight .....056
- Mose Allison: 7th Son .....057
- Steve Cropper: In The Midnight Hour .....058
- Booker T & the MG's: Something .....059
- Sam Cooke: Happy In Love .....060
- Ramblin' Jack Elliott: Tom Joad .....061
- John Lee Hooker: Boogie .....062
- Chillun Fred McDowell: Milk Cow Blues .....063
- Isaac Hayes: Never Can Say Goodbye .....064
- Lightnin' Hopkins: Mojo Hand .....065
- Memphis Slim: Rock Me Baby .....066
- Leo Kottke: Driving of the Year Nail .....067
- Tony Bennett: My Foolish Heart .....068

**A one-of-a-kind concept, unlike any before.** You always wished for the day you could choose your favorite music and create your own personal CD. Now you can! With new breakthrough technology, [www.musicmaker.com](http://www.musicmaker.com) lets you do just that.

**Choose from thousands of your favorite songs** from a wide variety of musical interests. YOU choose the song, YOU arrange them in the order you want, YOU personalize the disc with your own title and name. Each CD is custom manufactured exclusively for you, using the highest CD recording technology.

**The ultimate Music Service of the future is here.** We are currently building a huge data warehouse for all musical tastes: Classical, Jazz, Rock, Country, New Age, World and hard to find music. And when complete, we expect to have in excess of a million songs for you to choose from.

And our special *New Artist Section* lets you sample new and upcoming artists, a very affordable way to sample their songs and help build your collection.

**Add new excitement to your music collection! Visit our website at [www.musicmaker.com](http://www.musicmaker.com) now** to create your own personal CD. Listen to samples from thousands and thousands of songs from artists like: Creedence Clearwater Revival, Miles Davis, Ike & Tina Turner, Little Richard, Tony Bennett, Ella Fitzgerald and many, many more.

**Or you can create your first CD right from this page** and later shop the MusicMaker bi-monthly catalog, featuring hundreds of songs and artists!

music maker

**visit [www.musicmaker.com](http://www.musicmaker.com)**

OR MAIL THIS FORM TO: **The Music Connection Corporation**  
250 Exchange Place, Suite A, Hemdon, VA 20170

Yes, I want to create my own personal music CDs. Please send me my first CD with the songs I have selected below. Also send me a MusicMaker Catalog every other month so I can continue to create my own personal CDs.

WRITE THE NUMBER OF EACH SELECTION IN THE ORDER YOU PREFER:

MINIMUM OF 5 SONGS for just \$9.95 1 \_\_\_\_\_ 2 \_\_\_\_\_ 3 \_\_\_\_\_ 4 \_\_\_\_\_ 5 \_\_\_\_\_

Plus additional songs just \$1 ea (5 max.) 6 \_\_\_\_\_ 7 \_\_\_\_\_ 8 \_\_\_\_\_ 9 \_\_\_\_\_ 10 \_\_\_\_\_

FREE SELECTIONS. With your first CD, choose one FREE SONG for every 5 songs you order: FREE SONG #1 \_\_\_\_\_ FREE SONG #2 \_\_\_\_\_

Personalize your CD with your name and title for just \$1.00. UP TO 25 CHARACTERS: \_\_\_\_\_

(A shipping and handling fee of \$2.95 per CD and applicable state and local taxes will be added)

I AM MOST INTERESTED IN THE FOLLOWING TYPE OF MUSIC (Check 4): ☐ Jazz ☐ Blues ☐ Rock ☐ Classical ☐ Folk ☐ Country ☐ Alternative ☐ New Age & World ☐ Christian ☐ Metal ☐ Pop Nostalgia

PAYMENT METHOD (Check one) ☐ VISA ☐ MASTERCARD ☐ AMEX

Acct. No \_\_\_\_\_ Exp date \_\_\_\_\_

Name \_\_\_\_\_

Address \_\_\_\_\_

City \_\_\_\_\_ State \_\_\_\_\_ Zip \_\_\_\_\_

**Satisfaction Guaranteed.**

If there are any material defects, return CD within 30 days for prompt replacement or refund.

P-003

nology systems. The basic idea is that governments should compensate for market failures by supporting risky, long-run basic research that will generate new technology and products. Such advances will help the government provide for national security, environmental protection, and the health of its citizens, as well as lead ultimately to economic growth.

This system worked well enough, so long as innovation systems were contained within national borders. As science and technology have become global enterprises, however, the underpinnings of this policy must be questioned. The question becomes whether U.S. taxpayers should support science and technology activities that can, and will, benefit foreign-owned companies.

This is a tough question. But the answer, in my view, is a resounding yes. Foreign companies are investing considerable resources in American innovation, providing employment for large numbers of scientists and engineers and generating innovations and scientific discoveries that contribute to America's science and technology infrastructure. Thus it stands to reason that government policy should encourage foreign investment in U.S. research and technology, not restrict it. There are three key steps to begin with.

First, U.S. business leaders and policy-makers should support efforts by the Organization for Economic Cooperation and Development and others to establish a global framework for science and technology investments. A vehicle for this exists in the form of the Multilateral Investment Agreement—an international trade treaty. This agreement begins to eliminate limitations on foreign investment in R&D, such as those that restrict foreign participation in domestically funded technology programs, and

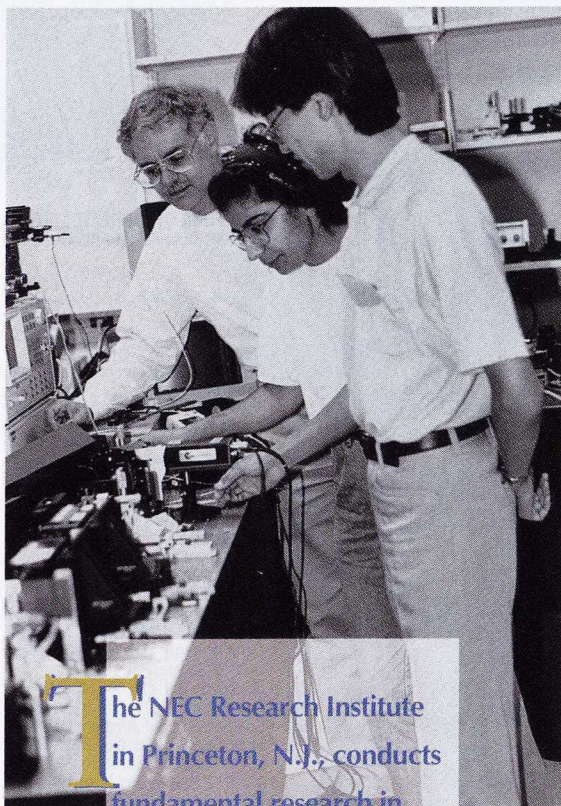
is thus a step toward creating a global playing field.

Second, U.S. science and technology funding agencies should promote foreign collaboration in science and technology.

Third, the United States should work with large investors in science, including Japanese and European companies, to develop joint funding and review programs for scientific and technological initiatives. Such international cooperation could help to eliminate the redundancies of today's system, in which many individual countries fund similar scientific work.

Furthermore, any policy measures that attempt to give U.S. companies an edge over foreign ones will inevitably provoke some sort of backlash as other nations respond in kind. The result would be a vicious downward spiral, in which all countries begin to impose tighter and tighter restrictions on one another. U.S. firms, which have a greater global presence than their overseas counterparts, would have the most to lose from such a trend. The best option for the United States is to embrace the new age of global innovation, and seek to attract R&D investment from all corners of the world.

Embracing the new realities of the global age of innovation is the only realistic path open. The United States has little choice but to take the lead in helping to establish a truly global environment for innovation. Our nation should lead, not only because we are the world's largest economy and the world's leading source of science and technology, but because we have the most to gain from a truly open and global system of innovation. ■



**T**he NEC Research Institute in Princeton, N.J., conducts fundamental research in computer and physical sciences. Here, Richard Linke (left) explores new materials that might be used to fabricate an optically switched transistor. Linke is working with a student from Princeton University (middle) and a visiting researcher from NEC in Japan (right).

# Discover...

THE SIGHTS AND SOUNDS  
OF PORTUGAL DURING OUR  
**PORTUGAL DISCOVERY PROGRAM**

**JULY 23–AUGUST 3, 1998**

("mit on the road: europe" PROGRAM ONLY: JULY 23–26, 1998)

**W**e begin with 4 days in Lisbon, visiting EXPO'98, the last world exposition of the 20th century, and participating in an exciting full-day "mit on the road: europe" alumni education program: "The New World: MIT's Contribution to Technology, Management and the Environment."

The program will be led by MIT President Charles M. Vest HM, MIT Professor David Marks of the Center for Environmental Initiatives and additional MIT faculty, to be announced. Welcome remarks presented by Portugal's Prime Minister Antonio Guterres, and responses to MIT faculty presentations provided by Portuguese heads of science and technology.



Private behind-the-scenes tours at EXPO'98 are planned as well as special evening events and tours of Lisbon and the surrounding areas. Next, we head north with the Alumni Travel Program and explore the charming towns of Portugal including:

Óbidos, Coimbra, Conimbriga, Guimarães and Porto. We will visit important archaeology sites, cruise the Douro River, meet with local MIT alumni, learn about the history, and experience the rich culture of Portugal. **The "mit on the road" program and the Alumni Travel Program to the north of Portugal may be purchased separately. Please contact us to be placed on the mailing list for this brochure.**



# Witness...

GEOLOGY IN ACTION DURING OUR  
**ICELAND PROGRAM**

**AUGUST 4–AUGUST 13, 1998**

(GREENLAND OPTIONAL EXTENSION AUGUST 13–19, 1998)

**D**r. William Brace '46, of MIT's Earth, Atmospheric and Planetary Sciences department will lead our group as we explore the island of Iceland, witnessing along the way her thermal springs, steam vents, bubbling mud pools and geysers. We will visit Heimaey on the Westmann Islands, the Vatnajökull Glacier and Lake Myvatn, where exist lava fields, boiling sulphur pits and volcanic cones. Our Greenland option takes us to the towns of Narsarsuaq, where we view the scenic fjords and icebergs by boat; Qaqortoq, which stands at the mouth of an extensive series of fjords; and Hvalsey, where we will see the best preserved Norse ruins in Greenland.

# Cruise...

THE CANALS OF ALSACE, FRANCE ON OUR  
**ALSATIAN SOJOURN**

**SEPTEMBER 30–OCTOBER 9, 1998**

**A**fter two days exploring the town of Strasbourg, we board our river barge, the M/S Lorraine, and cruise from Niderviller to Saverne cruising through the St. Louis-Arzviller inclined plane, comprised of 17 locks. Then it's on to Waltenheim, then Kraft, where we will learn about the art and science of beer making. We will visit the memorial sites of WWII located in Blutberg, and explore the towns of Breisach and Colmar. The region of Alsace possesses a rich cultural heritage, resplendent architecture and superb museums. Our group size will be an intimate one as the M/S Lorraine carries a maximum of 18 passengers.

## MIT Alumni Travel Program

MIT alumni, friends and *Technology Review* readers are welcome to participate.

Many more programs are scheduled for 1998. Please contact us for more information.

77 Massachusetts Avenue 10-110 Cambridge MA 02139 • 800-992-6749 • 617-253-8248 • fax 617-258-6211

[web.mit.edu/alum/www/Geo/Travel/](http://web.mit.edu/alum/www/Geo/Travel/) • [compass@mit.edu](mailto:compass@mit.edu)

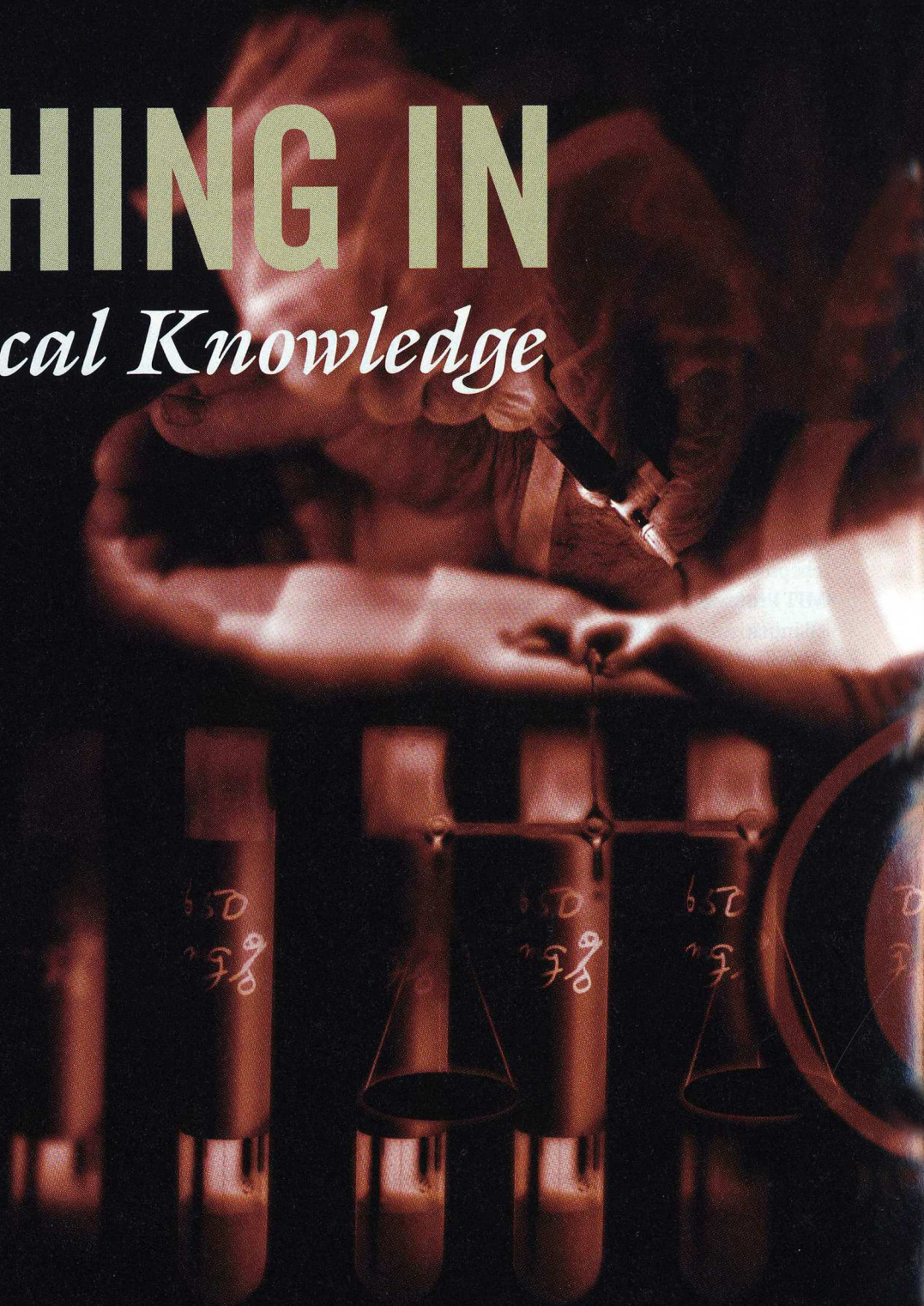
# CASHING IN

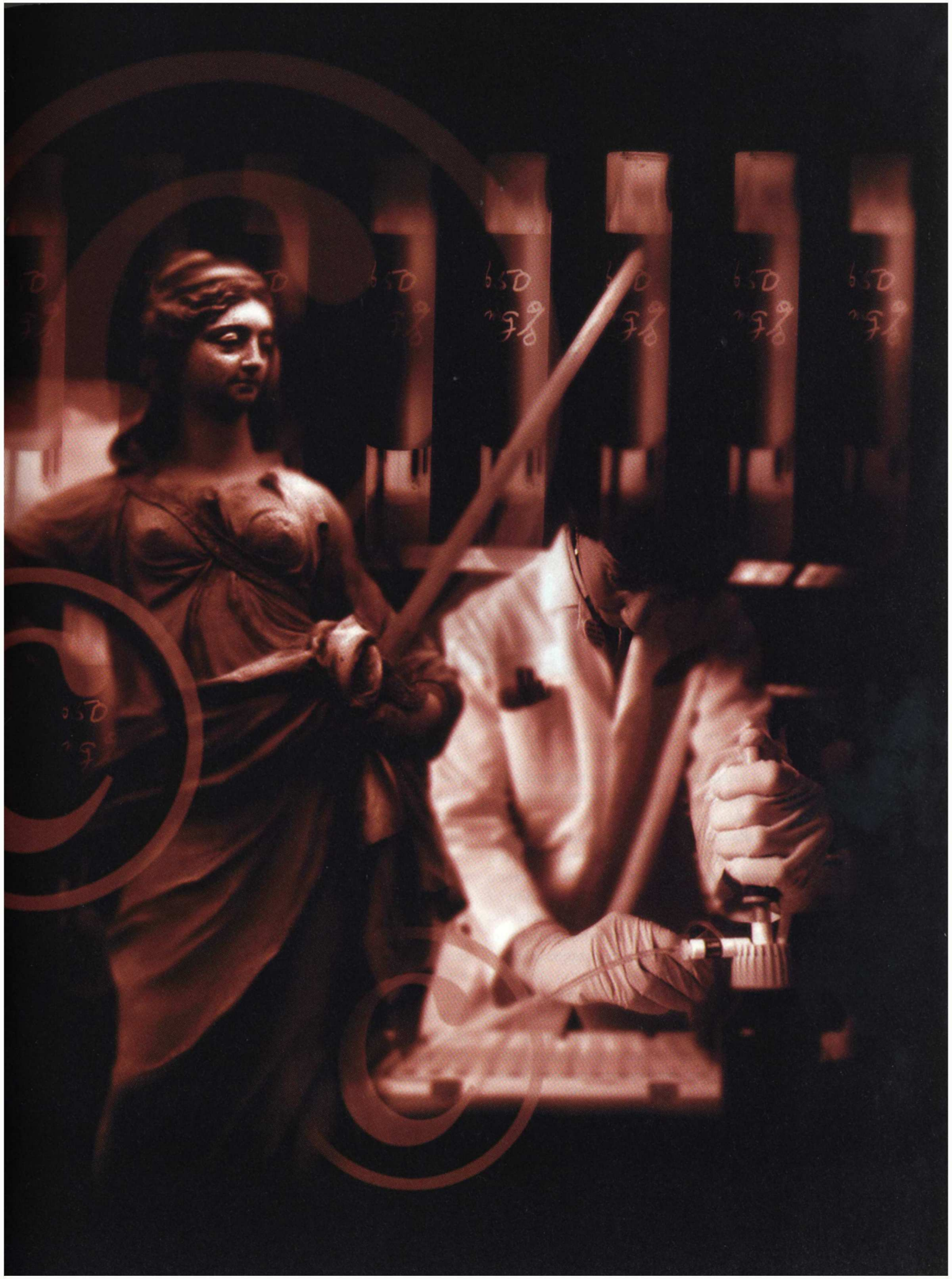
## *on Medical Knowledge*

BY SETH SHULMAN

In the emerging knowledge-based economy, a diverse and growing number of legal cases are challenging the Hippocratic oath's directive for doctors to share medical knowledge "without fee or covenant." In this troubling new legal environment, doctors are patenting medical methods, and demanding royalties for their use. Patients may go without drugs and treatments they once could have received. Is the drive for private profits exacting too high a price?

ILLUSTRATION BY ADAM LARSON





**E**ach year, nearly every pregnant woman in the United States takes a blood test to screen for the possibility that the child she carries will have a birth defect. By measuring the concentration of several substances in the pregnant woman's blood, the so-called multiple-marker blood screen can warn a woman that her baby likely has a birth defect such as Down's syndrome, a genetic defect that causes retardation.

One of the substances measured in this way is human chorionic gonadotrophin, or HCG, a hormone that women produce in the days after conception.

Since the mid-1960s, medical researchers have actively studied HCG and its role in building up the placenta. In 1989, a researcher named Mark Bogart was awarded a patent for a method based on an observation he'd made about HCG: that elevated levels of the hormone can signal the presence of Down's syndrome in a fetus.

Bogart, whose work was done in 1986 at the University of San Diego, didn't create a new device to obtain his patent. Instead, he observed a connection between the levels of HCG and the likelihood of Down's syndrome—and recognized the potential use of this correlation in a diagnostic test. Nor did his observation by itself result in the multiple-marker blood screen, since his was only one of three separate observations that make possible today's most commonly administered test. Nonetheless, combined with measurements of other factors in the blood, Bogart's research did open the door for the development of a diagnostic test that inexpensively alerts doctors when more accurate and invasive tests on a fetus might be warranted.

Bogart received U.S. Patent No. 4,874,693, affording him monopoly protection over a "method for assessing placental dysfunction." Now he has made clear his intention to turn his patent into dollars. Bogart claims the patent entitles him to a \$3 to \$9 royalty every time a lab administers the multiple-marker test. He has made good on his threat to sue labs, doctors' offices, and health maintenance organizations that refuse to pay.

Many are paying. According to Andrew Dhuey, Bogart's lawyer, laboratories owned by SmithKline Beecham are now paying Bogart royalties in excess of \$1 million per year. Recently, Dhuey says, the Arizona Institute for Genetics and Fetal Medicine agreed to Bogart's royalty demand covering all future screening tests, as well as paying \$90,000 in roy-

**C**ORPORATIONS AREN'T GOING TO INVEST THEIR MONEY IN ANYTHING "UNLESS THEY CAN GET A PROPRIETARY POSITION."

—PATRICIA GRANADOS

ties for tests conducted over the past six years. Given the test's widespread use, Bogart could earn as much as \$100 million in royalties from hospitals, laboratories, and medical research institutions over the patent's life.

Bogart's intellectual and financial claims have inspired outrage in some quarters of the medical community. As Arnold Relman, former editor of the *New England Journal of Medicine* told *Technology Review*, for Bogart "to claim private ownership rights over natural phenomena, the nature of disease, or human biology is a restriction of intellectual freedom that will stifle medical research."

Bogart refused to be interviewed for this story, but Dhuey, his lawyer, argues that Bogart is fully justified in law and logic. Dhuey notes that hospitals and labs "pay royalties every day on devices and on drugs that are being used, and it's unfortunate that they don't see that there's no fundamental difference."

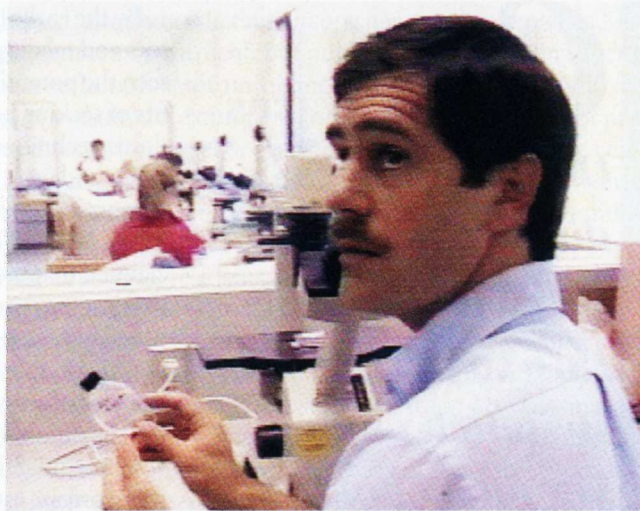
Bogart's claims are far from unique. He is one of thousands of medical doctors and biomedical researchers who have patented medical observations, surgical techniques, and other procedures, some as common as determining the sex of a fetus from an ultrasound image. These patent holders contend the procedures they develop are no less worthy of patent protection than an improved version of a catheter or x-ray machine.

Supporters of these claims believe that patents of this kind are essential for medical progress. Patricia Granados, a patent lawyer at the Washington, D.C.-based firm of Foley and Lardner who has litigated many related patent infringement cases, warns that without patent protection emerging industries like gene therapy and medical diagnostics will suffer. "It is questionable whether such industries will be able to obtain the investment money needed for research and development," Granados explains. Corporations aren't going to invest their money in anything, she adds, "unless they can get a proprietary position."

Welcome to the field of medical research on the cusp of the millennium. A stark and accelerating clash has emerged between the drive to privately own medical knowledge and techniques, and the tradition of freely sharing them to improve public health—a tradition enshrined in the Hippocratic oath, which mandates that every physician must teach the craft of medicine "without fee or covenant."

The clash has implications that go far beyond the philosophical underpinnings of the Hippocratic oath. For example, Bogart's royalty demand is greater in some cases than what an insurance company will reimburse labs for conducting the test. Already some labs have threatened to drop the blood screen, and public health officials worry that fewer health plans will offer it.

SETH SHULMAN, a frequent contributor to *Technology Review*, has also written for *Smithsonian* and *The Atlantic Monthly*. His forthcoming book, *Knowledge Wars* (Houghton Mifflin, 1998), chronicles problems in high-tech fields caused by the growing number of intractable disputes over intellectual property.



Mark Bogart, as seen in a CBS television news story

"If the patent is enforced, it will have serious consequences to the health care of women in this country," Mark Evans, professor of obstetrics and gynecology at Hutzel Hospital in Detroit told ABC News. "I believe in capitalism and rewarding discoveries, but there has to be a point where social responsibility takes precedence over greed."

### ***"A reward at the end"***

Patent infringement cases are very expensive in the U.S. legal system. They routinely cost litigants more than a million dollars. And their outcomes are notoriously unpredictable. So, though many doctors, hospitals, and patent experts scoff at Bogart's claim, some of the nation's most venerable hospitals, medical firms, and testing laboratories have followed their lawyers' advice and reluctantly paid Bogart's royalty.

Oakland, California-based Kaiser Permanente, the country's largest non-profit hospital chain and health maintenance organization, is an exception. It has not agreed to pay. Instead, it has challenged Bogart in court.

Mitchell Sugarman, Kaiser's director of technology assessment, says the HMO has contested the claim because of what it implies for its patients and the broader medical community. Kaiser expects to spend well over \$1 million to litigate this case, more than it would have paid in royalties. But Sugarman contends there is a "moral argument" to be won.

Joining Kaiser is a consortium of medical professional groups, including the American College of Medical Genetics, the American Medical Association, and the American College of Obstetrics and Gynecology. The group has offered Kaiser financial aid and free expert assistance. The organizations formed the consortium because in their view the Bogart case represents "a dangerous attack on the availability of an important diagnostic test for pregnant women and on public health policy in this country," says Michael Watson, the consortium's leader and vice president of the

***H*ospitals and labs "pay royalties every day on devices and on drugs that are being used, and it's unfortunate that they don't see that there's no fundamental difference" between that and a patent on a medical method.**

—ANDREW DHUEY, Bogart's lawyer

American College of Medical Genetics.

On the other side of the issue, the Biotech Industry Association is watching the Bogart case closely. David Schmickel, the association's legal counsel, argues that "medical professionals often ignore the fact that it costs tens of millions of dollars to bring a diagnostic test to market. This kind of research will not be done and those tests will certainly not reach the public unless there is a reward for the inventors at the end."

The issues raised by Bogart's patent are dramatic and humbling in their complexity. They are also new. Until the mid-1950s, the U.S. Patent Office did not issue patents on observations or procedures. Patent directives and patent-law precedents drew a hard line between devices, like catheters and x-ray machines, and procedures, like blood transfusions or cardiopulmonary resuscitation (CPR). Devices could be patented, but procedures could not. The longstanding view was highlighted over a century ago in the landmark 1862 case *Morton v. New York Eye Infirmary*, in which an inventor tried to claim ownership of the burgeoning medical practice of using ether as an anesthetic for surgery. The court invalidated the patent, dismissing it as



Congressman Greg Ganske

**Ganske warns that if Congress doesn't act, people will one day hesitate to perform the Heimlich maneuver on a choking diner for fear someone might sue them for violating a patent.**

nothing more than the “naked discovery of a new effect, resulting from a well-known agent, working by a well-known process.”

Before the advent of the knowledge-based economy, the rationale for drawing a distinction between procedures and devices seemed clear and easy to accept. Developing a medical machine or instrument often requires the inventor to invest significant capital. By granting a patent, the government allows the inventor the opportunity to recoup the cost—thereby encouraging the continued development of medical innovations. The refinement of new treatments, or biomedical insights, on the other hand, rarely entailed such costs, and rarely involved just one inventor or company. Instead, most of the advances came from researchers and practicing doctors sharing knowledge and further developing each other's insights.

The consensus was so strong that the idea of patenting medical knowledge could seem absurd. For example, in 1954, when Jonas Salk developed a polio vaccine, his funder, the March of Dimes, prohibited patenting or receipt of royalties on the results of its research projects. The notion of Salk individually owning rights to the discovery never entered the picture. When Edward R. Murrow, the renowned TV commentator of the day, asked, “Who will control the new pharmaceutical?” Salk scoffed in reply that the discovery belonged to the public. “There is no patent,” he said. “Could you patent the sun?”

Yet ironically, even as Salk was asking his audacious rhetorical question, the Patent Office's distinction between devices and procedures was beginning to erode, in concert with an expansion of the accepted notion of intellectual property in many disparate high-tech fields. Beginning with a fateful 1954 patent on a technique to treat hemorrhoids, the Patent Office became increasingly indifferent to the distinction between devices and procedures.

By the early 1990s, many doctors and medical researchers had seen the potential financial benefits of seeking patents on procedures, techniques, and observations, and were petitioning for patents in record numbers. In 1996, *Medical Economics* claimed that the Patent Office was issuing patents on medical procedures at a rate of 100 per month, double the rate of a decade before. Other estimates put the number far higher.

Unfortunately, developing more precise estimates of how many such patents there are is difficult. Patents in the medical field frequently involve both devices and methods in their claims. The category covering surgery does have a subclass explicitly devoted to surgical methods, and it catalogs 485 patents. However, one law firm's search estimated that as many as 134,000 other surgery-related patents likely contain ownership claims on techniques or methods in conjunction with

the use of an instrument or device.

### ***“That's an invention?”***

All these patents confront medical specialists with a profusion of private claims on methods, observations, and other knowledge that in the past doctors freely used and shared. Specialists from urologists to eye surgeons have received patent infringement threats.

In one of the best-known cases, several years ago radiologists around the country received letters attempting to exact royalties on a patent covering a technique for determining the sex of a fetus at 12 to 14 weeks with ultrasound. The patent—still valid—boils down to visually distinguishing fetal male genitalia from female. Many in the field derided the claim. As Chris Merritt, a radiologist at the Ochsner Clinic in New Orleans, puts it: “It's like saying you have a secret method for distinguishing the gender of patients when they take their clothes off for a physical. That's an invention?”

This claim, however, never reached the stage of litigation. The American College of Radiology publicly condemned the claim. Later the patent holder, obstetrics and gynecology specialist John D. Stephens of San Jose, California, withdrew his royalty demands.

The inherent complexities of the biomedical knowledge economy are probably not going to be resolved by the patent examiners alone. Patent examiners are seldom medical practitioners, and they typically base their decisions on searches

of published work aimed at finding whether anyone has previously reported a procedure or treatment. But published works are often a poor reflection of the unfolding state of medical knowledge; as a result, the examiners grant patents for many procedures that are not novel or even noteworthy. Many ownership claims cover skills most hospitals expect doctors to learn during their medical residencies, skills one generation of doctors has traditionally passed to the next.

For instance, almost all surgical residents are taught how to suture the stomach to the intestines (to treat bleeding ulcers or stomach cancer); a physician owns a patent on a technique for this procedure. Similarly, cosmetic surgeons around the world know how to make slits in a skin graft to expand it; another physician holds a patent covering a technique for this procedure. Still another doctor owns the simple procedure of treating iron deficiency by administering iron under the tongue.

Given the thousands of procedures doctors perform every day, "the proliferation of patents on medical and surgical procedures becomes a frightening prospect," says Robert Portman, a patent lawyer at the Washington, D.C. firm Jenner & Block. It could "wreak havoc on the delivery of medical services."

Portman litigated one of the most publicized of the recent medical patent cases. The case generated widespread attention to the issue when it came to trial in 1995—and it helped inspire congressional legislation in 1996. In 1992 Arizona eye surgeon Samuel Pallin received a patent on a type of incision, used in cataract operations, that required no stitches to heal. Once Pallin received the patent, he demanded royalties from fellow eye surgeon Jack Singer, who also used the procedure and had written about it in medical journals. Pallin threatened to force Singer to stop using the technique unless Singer paid.

To Pallin, the patent reflected his rightful intellectual property. "We don't think of it as greedy when a scientist gets a royalty for coming up with a new [drug] compound. It is ridiculous to say that this is any different," he retorted to the *Wall Street Journal* after medical professional societies criticized him for his private ownership claim.

But to Singer, the patent was an affront. An eye surgeon at the Hitchcock Leahy Clinic at Dartmouth Medical College in New Hampshire, Singer had already perfected the procedure in his own practice. He did not patent it. In fact, he taught it to his students and shared it at symposia with other doctors from around the world. Singer maintains that he and many other eye surgeons had developed this type of stitchless incision simultaneously.

Pallin's claim ran counter to everything Singer believes about his profession, Singer

explains. "It would have been much easier to purchase Pallin's license and let others worry about the problem," he says. "But from the beginning, I knew I had to fight this as a matter of principle."

Three years and more than half a million dollars later, Singer won a legal victory. But the victory did not help Singer establish the principle that medical knowledge cannot be patented. Singer won simply because he could document that he had performed the incision for one month prior to Pallin's patent claim.

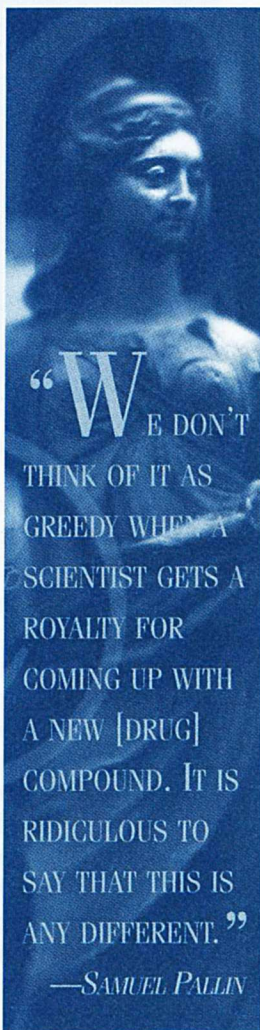
Singer's assertion that medical procedures must be shared among practitioners did find a broader following, however—in Congress. Rep. Greg Ganske, R-Iowa, a plastic surgeon by training, sponsored a bill to ban patents on medical procedures, a policy followed by some 80 other industrialized nations. Ganske warned that if Congress didn't act, people would one day hesitate to perform the Heimlich maneuver on a choking diner for fear someone might sue them for violating a patent.

But other than banning private patents on nuclear-weapons-related inventions during the Cold War, Congress has been loath to set limits on the robust U.S. patent system. During the 1996 congressional hearings, lawyers from the

American Intellectual Property Law Association, the Intellectual Property Section of the American Bar Association, and the Biotechnology Industry Organization argued that the United States risks a "domino effect" that would squelch technological progress if it systematically excludes certain types of patents on policy grounds.

These parties argued that Rep. Ganske's proposed bill would invite other countries to weaken their patent laws at a time when the United States is pushing these countries to toughen them. The move could embarrass the United States internationally or, worse, even put the nation out of compliance with the intellectual property treaty arrangements of the General Agreement on Tariffs and Trade (GATT) negotiations—arrangements the United States was working to bolster in the international community.

The final legislation, signed by President Clinton in the fall of 1996, sought a middle ground between the two arguments. It specified that doctors and researchers can receive patents on medical procedures, but they cannot sue to recover royalties from other medical practitioners who use the procedures. In other words, Pallin could seek a patent today, but could not sue Singer. And if Pallin won a patent today, the law would make it effectively worthless, little more than an empty professional accolade. Yet, the U.S. government still preserves Pallin's right to claim ownership over his discovery.



The congressional compromise reflects a deep-seated national conflict on this issue. The medical-procedure patent law will curb some of the worst incursions of private ownership claims into the shared terrain of medical education. But increasingly, as bitter intellectual property fights like the Bogart-Kaiser case spread throughout the biomedical field, Congress' actions may prove inadequate to address the emerging clash between private profit and the shared "infostructure" of medical education. The legislation will not stop all legal battles. For example, it does not apply retroactively to existing patent claims, which leaves thousands of actionable medical-procedure patents on the books.

More important, the law does little to address similar problems arising in high-tech biomedical research. The legislation focuses on medical procedures, so it does not explicitly cover the vast number of claims like Bogart's that involve insights about the body's functions that researchers and companies can use to create diagnostic tests or novel treatment approaches.

Indeed, just months before President Clinton signed the congressional law to limit the value of patent claims among medical practitioners, he signed legislation that actually expanded patent rights in biomedicine. That law gives explicit backing to what may be the broadest patent in medical history: on *ex vivo* human gene therapy.

In 1990, a team of researchers at the National Institutes of Health (NIH) made medical history when they employed a new technique called *ex vivo* human gene therapy to successfully treat two girls with a rare genetic disorder. In this type of gene therapy, doctors remove the cells from the patient and alter them in a lab, outside of the body. The medical team took the girls' white blood cells, inserted an altered virus that would correct their genetic disorder, and reintroduced the corrected white blood cells into the girls' bloodstreams.

With strong legal advice, three members of the team managed to parlay the experiment into a patent on all *ex vivo* human gene therapy. The claim is so broad that doctors around the country were shocked when the team won the patent. "Deep disbelief, I'd say that's what most people feel about the breadth of the patent," Joseph Glorioso, head of the department of molecular genetics and biochemistry at the University of Pittsburgh told the journal *Nature*. "This is analogous to giving someone a patent for heart transplants."

Dusty Miller, a key member of the original human gene therapy team—who was not on the patent and who is now a researcher at the Fred Hutchinson Cancer Center in Seattle—says such a patent shouldn't exist, or, at the very least, should be defined far more narrowly. As he put it, the patent

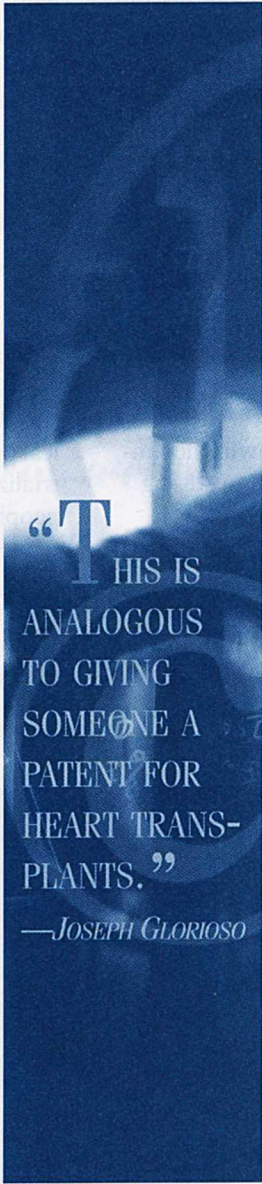
amounts to "another big step toward the bizarre world where people stake claims to the natural processes of the human body."

Complaints like Miller's grew louder when the team sold the exclusive rights to this entire new and promising field of medicine to the highest bidder. Ultimately, after various corporate mergers and acquisitions, those rights landed in the patent portfolio of Swiss pharmaceutical giant Novartis. The patent, and Novartis' control of it, has far-reaching effects. Novartis can exact royalties from anyone seeking to use the technology and, because of this, those treatments that come to market will likely cost more.

Another set of problems posed by such patents is typified by a bitter, ongoing case involving Baxter International. Baxter, a large pharmaceutical and health care firm, claims to own a broad license on the technology related to a particular antibody that can be used in bone-marrow transplants for patients with breast cancer and lymphoma, among other diseases. Even though no comparable Baxter product is yet on the market, the company has legally blocked a small competitor—a Bothell, Washington-based firm called CellPro—from marketing its own similar treatment while Baxter tries bringing its own version through the lengthy Food and Drug Administration (FDA) development and approval process. The problem is that Baxter's action could deny cancer patients around the country a promising FDA-approved treatment.

Andrew Yeager, director of bone-marrow transplant programs at Emory University, where physicians have been using the CellPro treatment with some success as a last-ditch effort to save lives of children suffering from acute leukemia, lamented to the *Seattle Times*: "It's unfortunate that these sorts of things in corporate America can threaten therapeutic clinical trials and potentially life-saving therapies."

More than three dozen members of Congress, the American Cancer Society, several patient advocacy groups, former U.S. Senator Birch Bayh, Jr., and former Carter White House Counsel Lloyd Cutler made an appeal on CellPro's behalf to Department of Health and Human Services chief Donna Shalala. They asked her to exercise the government's right to intervene in patent disputes that stem from publicly funded research in "extraordinary cases" where the dispute threatens public health. "CellPro's request is simple. While the



"THIS IS  
ANALOGOUS  
TO GIVING  
SOMEONE A  
PATENT FOR  
HEART TRANS-  
PLANTS."

—JOSEPH GLORIOSO

court case is allowed to run its course, an FDA-approved product must remain on the market, available to any and all cancer patients who need it," Bayh and Cutler wrote Shalala.

The government denied the request. NIH Director Harold Varmus, who made the ruling, said he was convinced the courts would insure no one was denied treatment. Varmus was undoubtedly swayed by the many equally influential voices arrayed against such action, such as Stanford University President Gerhard Casper. Casper wrote to Varmus that to intervene would set a precedent that "would pose a grave threat to university-industry partnerships" and even "put into jeopardy the kind of investments needed today to take medical discoveries through the lengthy processes necessary to bring them to the public."

## ***A lottery system***

The intent of the patent system is, as Abraham Lincoln once put it, to add the fuel of interest to the fire of genius by granting inventors financial rewards. In the knowledge-based economy, however, the researchers who obtain the patent on a biological process are frequently not the ones who do the work to bring a product to market. Even *Forbes* magazine, the self-described capitalist tool, complained about this aspect of the patent system. *Forbes*' editors wrote in 1994 that the U.S. patent process has too often "become a lottery in which one lucky inventor gets sweeping rights to a whole class of inventions, and stymies development by others."

*Forbes* was not speaking specifically about the biomedical field, but the observation seems prescient as the Bogart/Kaiser case heads to court in California. But is this kind of a lottery just? Should anyone be allowed to patent a function of the human body, or a medical method or procedure? As in most patent infringement cases, the court will likely not tackle those broader questions. Instead the case will probably focus on narrow legal questions. Much of Kaiser's case, for example, will center on the argument that the modern-day multiple-marker prenatal test is only distantly related to the original research Bogart patented.

Bogart noted a correlation between Down's syndrome and high levels of the hormone HCG. But, in as many as 30 percent of cases, the elevated HCG levels do not correspond to the presence of the birth defect. To make a more reliable test, researchers developed a technique that drew upon other insights similar to Bogart's to screen the blood for the levels of two chemicals aside from HCG. The combined indicators considerably enhance the efficacy of the test not only for Down's syndrome but for other birth defects as well.

Mike Jacobs, an attorney at Morrison & Foerster representing Kaiser Permanente in the case, notes that articles in the medical literature, including a letter in the prestigious British medical journal *Lancet*, on the correlation between HCG and fetal abnormalities actually predate Bogart's observation. Jacobs hopes that fact may ultimately invalidate Bogart's claim. Even if Bogart does deserve credit for discovering—or at least sharpening—our realization of the



*Jack Singer*

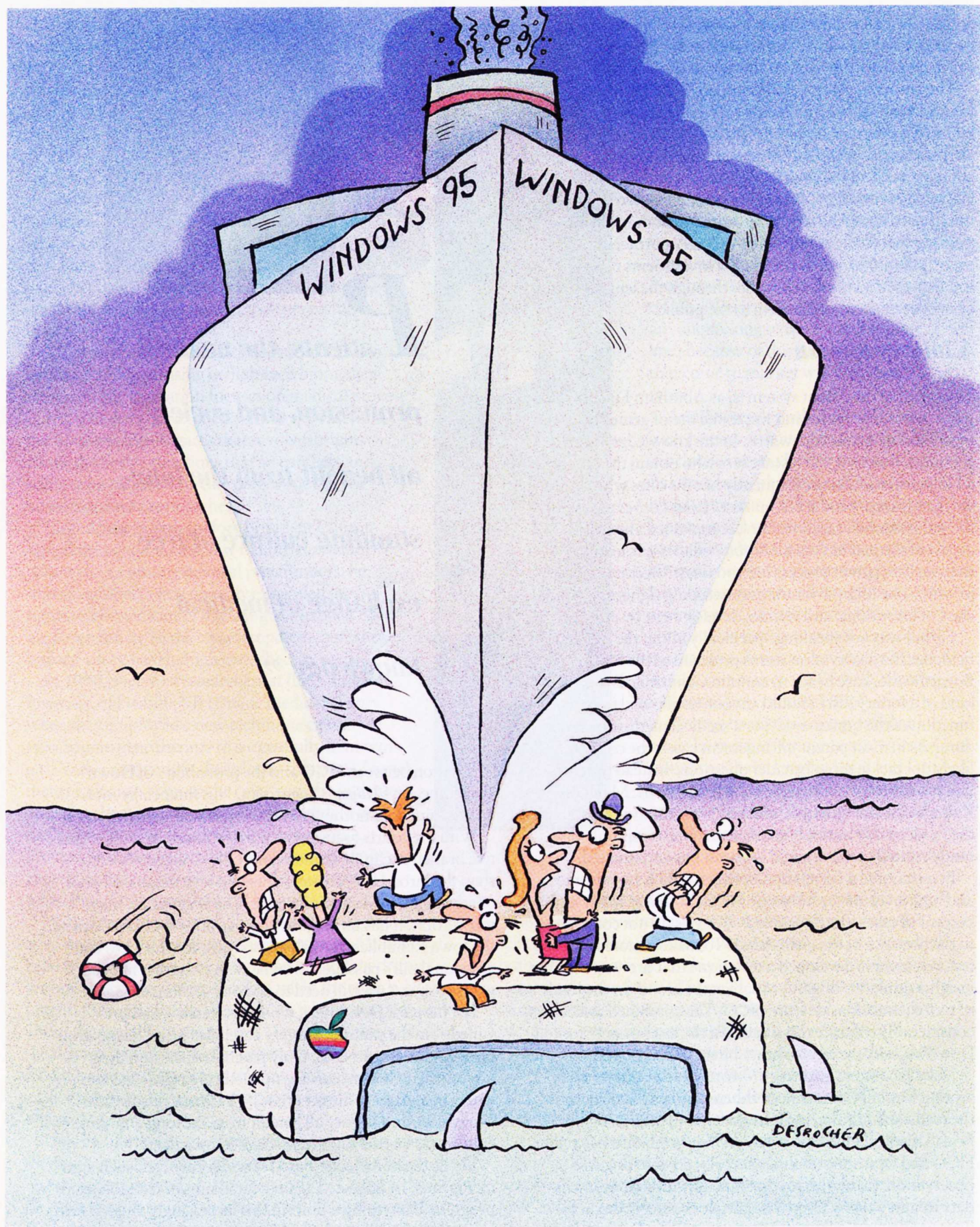
“**P**atients, the medical profession, and society all benefit from the long-standing culture of free exchange of medical knowledge.”

correlation between HCG and the probability of Down's syndrome, says Kaiser's Sugarman, "his financially motivated claim does nothing to benefit medical science."

With the courts focusing on narrow issues, and the executive branch declining to intervene, only Congress is left to stem the inroads of private ownership into the shared pool of advancing medical knowledge. The Bogart case may inspire that. It has undergone close scrutiny by Greg Ganske, the Iowa Republican largely responsible for the 1996 congressional bill's passage. "Maybe with examples like this," Ganske says, "we will need to go back at this issue again."

For his part, Jack Singer, who persevered—and prevailed—in the cataract-surgery case, says he is "deeply troubled" by the Bogart case. Only patent owners and their lawyers benefit from carving up medical knowledge into privately held parcels, Singer argues. "Patients, the medical profession, and society all benefit from the long-standing culture of free exchange of medical knowledge."

But as the knowledge-based economy evolves, such arguments must be balanced against the claims of technological progress. If anything is clear in this increasingly tangled field, it is that there will not be simple answers anytime soon. ■



# To Mac or Not to Mac

*One Apple devotee's excruciating purchase dilemma*

**BY DAVID SHENK**

Many years from now, I'll be hunched over in a creaky old pine rocker on the porch of my retirement home. For hours at a time, I'll sit staring at the trees, lost in thought. Then a passing car will startle me out of my reverie and suddenly I'll begin to blurt out words like an old radio whose short-circuited wiring has accidentally righted itself. My utterances might seem incoherent at first, but whoever takes a moment to listen will quickly realize that they're not incomprehensible, merely ancient: "MacPaint ... AppleShare ... ImageWriter ..." • • • I will tell anyone who will pretend to listen, "I was a Mac person." • • • Maybe I'll get really lucky and catch the ear of a young history buff. She will recognize some of my strange utterings from her History of Technology class and understand right away that I come from the dawn of the Age of Personal Computing. With wide eyes and hushed voice, she'll want to know if I ever saw a Macintosh with my own eyes. I'll tell her truthfully and in all modesty, "I owned one." • • • The Mac will presumably be pure history by then.

## Every day seems to bring more bad news

for Apple and its famously loyal customers: "APPLE LOSES \$708M," "APPLE TO SLASH WORK FORCE BY 30%," "GATEWAY 2000 OVERTAKES APPLE IN EDUCATION MARKET." One particularly dark moment came last fall, when Yale University officials declared that after 2000 the university network will not guarantee support for the Mac—until recently the most popular machine on campus. This public abandonment threatens to undercut Apple's strategy of falling back on a few niche markets, notably education; for longtime Apple users, it is a betrayal tantamount to telling an aging Nobel Prize-winner that his services are no longer needed.

These, then, are tough times for any Mac person: to watch the steady demise of the company that invented this "insanely great" machine; to see frightened school principals and college deans abandon this elegant, intuitive platform; to see colleagues, friends, and even family members, good and loyal Mac people, throw in the towel, however valid their reasons—price, software selection, peripheral availability. *Wired* magazine's cover story last year on the embattled company featured a collection of former Mac loyalists who have gone over to Windows for one reason or another. It was agonizing to read the list of high-profile defectors.

The question that has been disturbing me recently is: *Should I join them?*

I realized a few months ago that I needed to buy a new computer. The last machine I bought was a PowerBook 180, purchased in 1993. It has a grayscale monitor, doesn't run a

lot of Internet software and, after four years of enthusiastic use, shows a fair amount of wear and tear. I try to avoid getting caught up in hardware and software upgrade mania—upgrading just for the thrill of it or in response to the pervasive cultural anxiety about falling behind. But sometimes there are good reasons to upgrade. Since I now perform a good portion of my research on the Web, it is time to step up to a quicker machine with color and more memory.

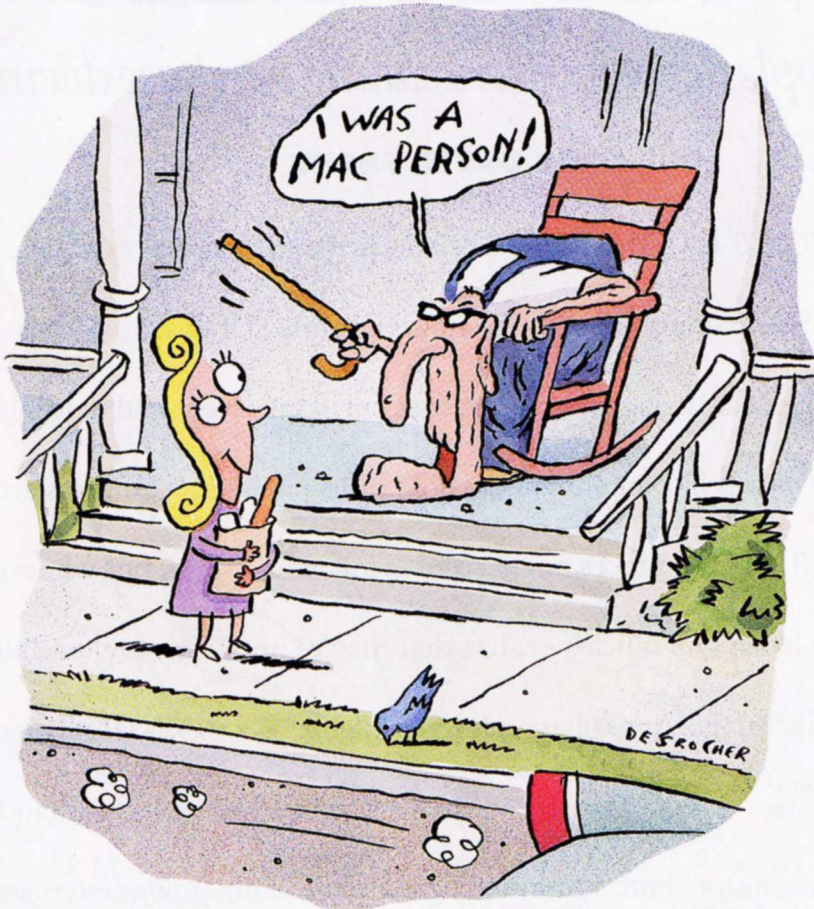
I phoned my brother Josh to tell him that maybe the time had come to switch to Windows: "Everyone else seems to be doing it."

"David," he gasped, "you're not serious!" This from someone who has been forced to use Windows at his place of business. Knowing that I have the freedom to stay with Mac, he couldn't believe I would even consider defecting.

It's not that I have become dissatisfied with the Macintosh. On the contrary: After 13 years and nearly as many hardware upgrades or outright purchases, I retain my reverence for the machine that helps me think and write my best. The Macintosh was, after all, the first personal computer to capture the popular imagination. Before the

Mac, nontechies didn't have much interest in personal computers for one simple reason—they weren't personal. They were *computers*—big ugly calculators that one could wrestle into performing calculations or type on without having to use White-Out™.

The Macintosh changed all that. Its famously intuitive graphical user interface, which put aesthetics on equal footing with function, turned the personal computer into a tool whose power derived not from its calculating capabilities (on that front, the Mac was no powerhouse) but from its ease of use. "The interface makes the teeming, invisible world of zeros and ones sensible to us," writes Steven Johnson in his



DAVID SHENK is author of *Data Smog: Surviving the Information Glut*.

terrific new book, *Interface Culture: How New Technology Transforms the Way We Create and Communicate*. "There are few creative acts in modern life more significant than this one, and few with such broad social consequences."

The cruel irony at work in the apparent disintegration of Apple is that as Mac has won the war of ideas, it has simultaneously lost the contest for financial preeminence to its imitators. "When Windows 3.0 swept the world, so did Apple's concept of beautiful software," writes Yale computer scientist David Gelernter in his book *Machine Beauty: Elegance and the Heart of Computing*. "Pushing beauty instead of old-fashioned DOS ugliness, Microsoft emerged as the uncontested leader of the desktop computing world." Windows now has a 70 percent market share—to Mac's 7 percent—and is gaining.

In the face of that juggernaut, I told Josh, I felt it was important to keep an open mind. Mac users are frequently

Yes, I had my share of peripheral installation trouble and Internet connection trouble. I spent hours on the phone waiting for tech support and hours more actually talking to technicians as they helped me work out this or that kink. On the whole, getting going was somewhat more difficult than it's ever been with a Mac. But since neither platform is guaranteed to be headache-free, these differences don't mean much to me. If people want to live truly simple lives, they should avoid buying complex machinery.

Mac friends may toss virtual rotten eggs into my electronic mailbox for saying this, but I found Win95 to be wonderfully intuitive, even for someone who has spent many years getting used to another system. In fact, I was startled to discover that a few Win95 features were clearly superior to their counterparts on the Mac. Using the all-purpose "Start" button in the lower left-hand corner of the screen, for instance, I could effortlessly choose almost any function offered by the com-



*Maybe much of the magical feeling I have about the Mac is just wonder at the process of writing and the mysteries of creativity and intellectual growth.*

derided as zealots whose fiery devotion to the Mac defies all reason. I like to think of myself as fairly level-headed. I'd hate to look back on my life from that porch rocker and realize that I'd wasted fistfuls of money staying true to an increasingly inferior brand. I'd also be ashamed to discover that I had duped myself into ascribing more power to the Mac than it deserved. Maybe much of the magical feeling I have about the Mac is just wonder at the process of writing and the mysteries of creativity and intellectual growth—intangibles for which one is naturally tempted to find a physical totem.

For all these reasons, I resolved to consider Windows seriously. I called a few PC manufacturers and arranged to borrow some "Wintel" machines. I also called up Apple and told them that I was thinking about abandoning the Mac. Would they please cooperate by letting me borrow one of their hot new PowerBooks for a little while? They graciously agreed to assist me in my experiment.

For my preview of Windows 95, Toshiba sent me its Portégé 300CT and Fujitsu sent its Lifebook 655T. Both are four-pound notebooks that conveniently dock into CD-ROM/floppy drive units. I also spent some time with Gateway's P5-133 desktop. And what I found, much to my surprise, was this: Windows 95 is terrific.

And all windows can collapse to the bottom of the screen in an orderly fashion, making it easier to juggle lots of documents and programs at once. Even the much-touted Mac OS8 doesn't provide these seemingly obvious conveniences. (Mac's answer to window clutter is collapsible windows that suspend the title bars wherever they happened to be in the screen, a laughably useless gimmick.)

And then there's the guilty pleasure of being in Bill's corner. The Justice Department may not be too happy about Microsoft's market dominance, and as a consumer advocate, I'm not necessarily thrilled about it either. But as a plain old consumer, I *like* the fact that my operating system, word processor, Internet browser, e-mail program, and scheduler are all designed by the same company to work in seamless synchrony. I *like* my software shopping to be a no-brainer, consisting simply of scouting for the Microsoft logo. I *like* my software company to be a financial titan, guaranteed to deliver timely upgrades on all my programs as long as I live.

More than anything else, discovering Win95's ease brings an enormous personal sense of relief. As many of us have entered our second decade of Mac use, we've carried with us the deep fear that we are headed for oblivion, like romantic adventurers who find themselves driving off a cliff. Having

sampled Windows 95 for myself, I now realize that Apple could crumble tomorrow and I would come out all right. David Gelernter is correct: the essence of Mac has swept the world. The war of ideas is over, and we're all winners.

Deciding whether to abandon the Mac is a two-part exploration. Having answered question one—"Can I thrive with Win95?"—in the affirmative, I now faced question two: "Is there a compelling reason to leave Mac now?"

Answering this question, I have come to believe, is a matter of choosing the correct metaphor. Is buying a new Mac this year like buying a Porsche 911 or a Sony Betamax? Both are superior machines; neither boasts an impressive market share. Porsche parts may not be compatible with market leaders Toyota, Ford, and Honda, but they are nonetheless readily available (albeit pricey). Most important, the car rides

First, Porsche may not be a top-selling car, but it sells well enough to keep lots of Porsche repair shops in business. Mac's 7 percent market share may not sound like much, but there are approximately 20 *million* Mac OS computers in operation right now. That's a substantial market by any measure, one that Microsoft and many other software and hardware vendors profit from handsomely. (Remember: Microsoft was producing and profiting from Mac software when there were fewer than a million Macs in circulation.) In fact, because of the enormous growth in the PC market, it's quite possible that even if the Mac market share slips to just a few percentage points over the next couple of years, the actual size of the Mac economy could keep on growing.

Even if Apple stopped selling Macs tomorrow, there would be a very healthy market out there for many years to come.



*Having sampled Windows 95 for myself, I now realize  
that Apple could crumble tomorrow and I would come out all right.*

beautifully on almost any road. Loyalty to the Porsche may seem eccentric, but the choice of driving system does not prevent one from getting where one wants to go or from enjoying the ride.

The Betamax, on the other hand, was a terrific machine that quickly lost its value for those who were unlucky enough to purchase one in the mid-1980s. A friend of mine in college clung proudly to his Betamax, touting its superior technology. But the vast majority of consumers chose the cheaper, if inferior, VHS machines, and Betamax "software"—video tapes—never developed into a viable market. My friend wound up playing the same few movies over and over again. Betamax proved that a superior technology can also be a useless technology if the market so dictates.

Some folks will say the Betamax analogy is the right one. It takes about 90 seconds in any software store to realize that there are vastly more titles available for Windows than Mac. The Windows user has many more choices among peripherals like printers and CD-ROM drives as well and tends to pay less to boot. Will Mac's market share shrink inexorably to zero? If Mac is destined to slide into oblivion like the Betamax, I'd be a fool to buy one.

But to my mind, there are at least three good reasons why the Porsche analogy works and the Betamax analogy fails.

Since Mac owners tend to use their machines longer than PC owners before upgrading, the Mac market is guaranteed to thrive at least through the end of the century.

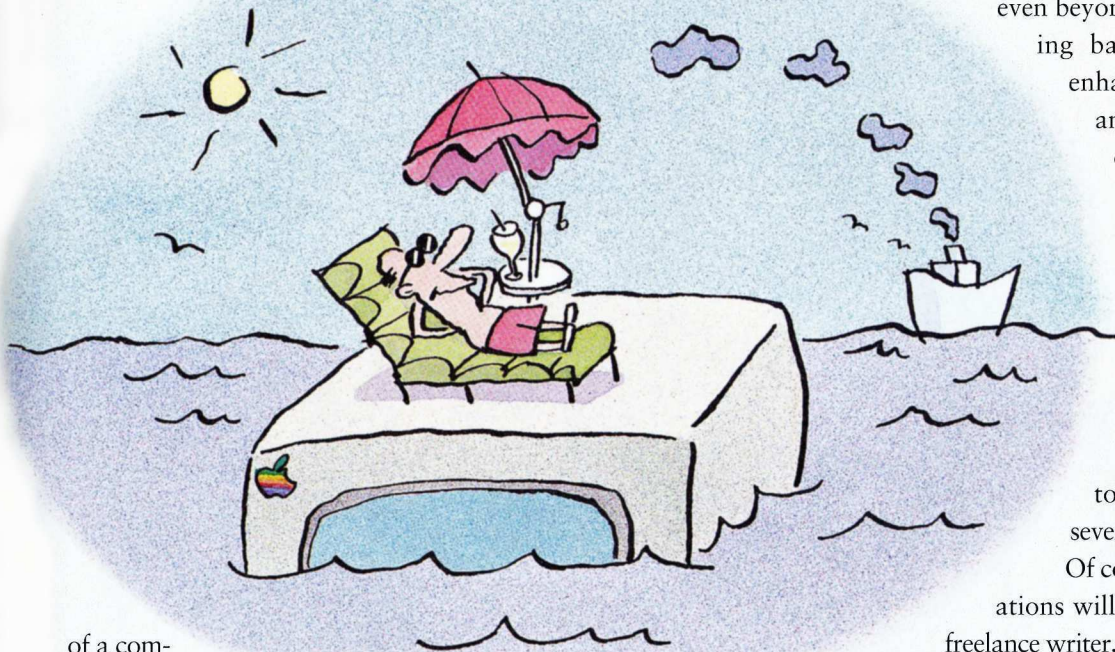
Second, the Mac still has four wheels and chugs unleaded gasoline. That is, despite the apocalyptic visions conjured up by headline writers, it continues to provide the services that many of us are after (20 million of us, apparently). Not only is the Mac still as user-friendly as complex machines come; it uses software similar or identical to the most popular applications available on Windows. As if to reinforce this point, Bill Gates publicly committed Microsoft last year to solid support for MS Office and Internet Explorer for the Mac for years to come. What has come to be unfairly regarded as an oddball specialty computer actually drives as well as anything else on the information superhighway.

Finally, it's a damn good car. I drive a Mac PowerBook for the same reason that car enthusiasts spend weekends behind the wheel of a 911: superior aesthetics, superior performance. We drive not just because we have to, but because we want to. We not only get to where we want to go; we also enjoy the ride.

That's not to say that there aren't other wonderful machines out there. But there's something very special about the Mac that people really seem to miss when they leave it

behind (I've listened to their groans). Asking them to explain it is like asking a wine expert to explain the difference between a superb wine and a merely good one: it's a wordless experience. Those who come to Mac from Windows, like those who have never acquired a taste for fine wine, may never appreciate what they're missing. But to those attuned to fine distinctions, that indescribable difference is deeply significant.

The designers at Apple have always understood that the aesthetics



of a computer is every bit as important as its technical performance and that a personal computer is not merely a tool but an extension of the user's mind and body. It assists and complements us in a range of subtle ways—it serves at once as notepad, rolodex, and library; it adorns our desks; it is something we step into as we would a piece of clothing. Just as a superb meal always begins with pleasant lighting and the warm greeting of the maitre d', so it is that an exceptional computer is a pleasure to look at, listen to, touch—even before it's switched on.

The expensive and consequential task of choosing a computer involves a wide range of considerations, including compatibility, aesthetics, cost, comfort, and performance. A year or two before his celebrated return to Apple, Steve Jobs stirred up considerable turbulence when he revealed to the *New York Times* that, on a shopping excursion to buy his daughter a laptop for college, he was so disappointed in the

PowerBooks, he bought her an IBM ThinkPad. Today, I think Jobs would buy his daughter a PowerBook, and not just because he is (as of the writing of this story) de facto chairman of Apple, but because the current line of PowerBooks is sensational. They are attractive, comfortable, quick, and mobile. Yesterday, I bought one myself—the new four-pound 2400/180c. I'm still getting used to the slightly cramped (but intelligently designed) keyboard; aside from that, it is everything you could ask for in a laptop: light enough to take everywhere and fast enough to keep me

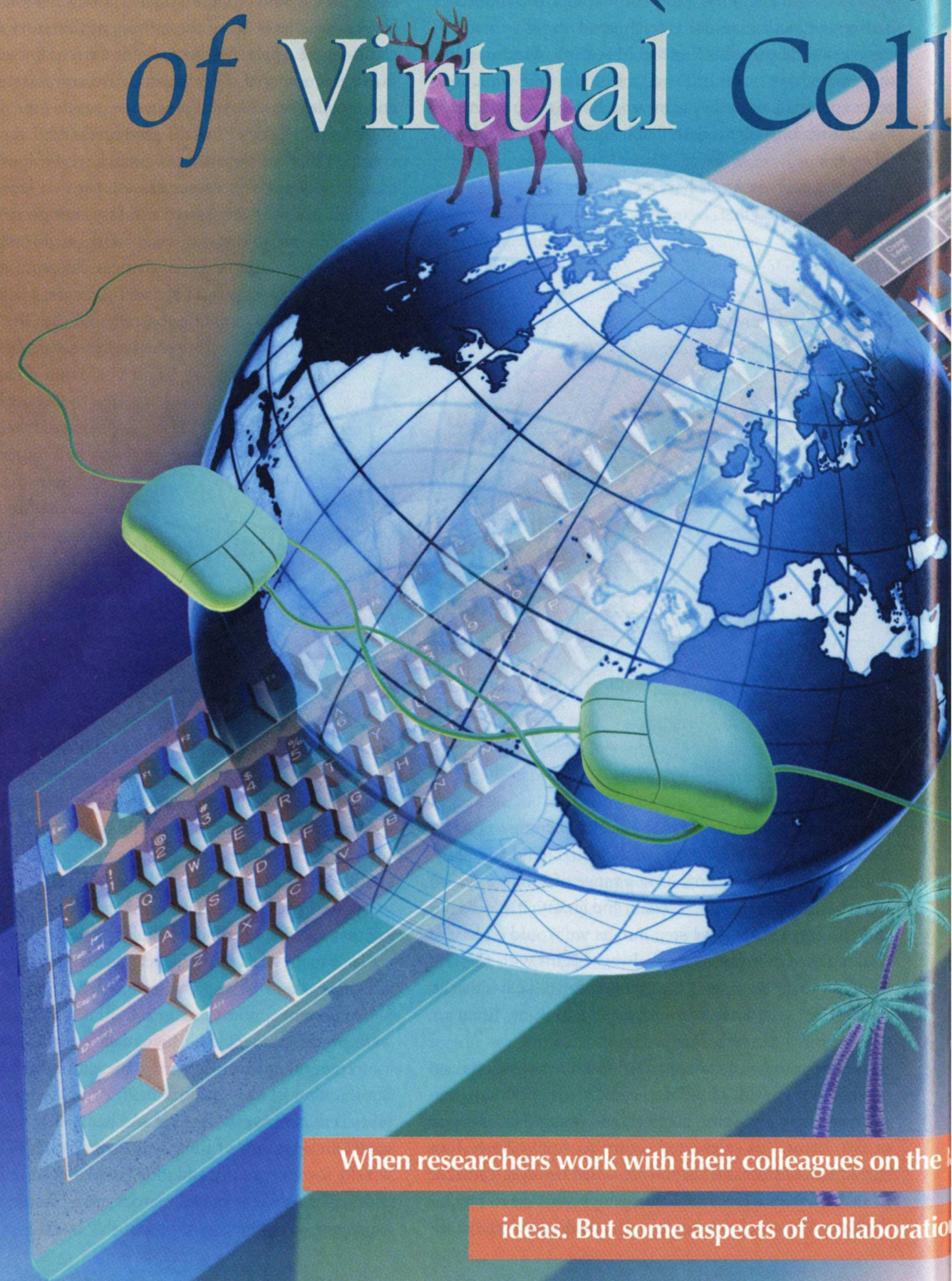
from rolling my eyes, with a vibrant active-matrix screen that can adjust to any angle even beyond 180 degrees, a long-lasting battery whose life can be enhanced in a variety of ways, and a case that is easy on the eye and to the touch. And in ways that only fellow Mac users will understand, it both expresses and evokes the fundamental human desire to create works that are not merely functional, but beautiful. With this machine, I expect to enjoy the ride for another several years.

Of course, few readers' considerations will be identical to mine. As a freelance writer, I work alone in a freestanding home office. If I were thrust into a Windows-based office environment tomorrow, I'd probably be more inclined to use that platform. And I could do so, as I've discovered, with few regrets.

Still, Mac has that special "look and feel" that makes it worth the loyalty. In fact, my brother called the other day to say that in defiance of his workplace network, he is switching *back* to the Mac. He's figured out that all it will really take is a little extra disk-swapping from time to time.

Computers connect us to each other in important new ways, and no one would go out of their way these days to buy a computer that's truly incompatible with other computers. But for many of us, the far more important type of compatibility is that between the user and his or her machine. We spend an awful lot of time—most of our lives—trying to wrestle some creativity and intelligence out of these plastic boxes. We owe it to ourselves to try to make the enduring experience as fulfilling as it can possibly be. ■

# *The Virtues (and V* *of Virtual Coll*



When researchers work with their colleagues on the

ideas. But some aspects of collaboration



# ices) eagues

BY NANCY ROSS-FLANIGAN

**F**OR YEARS, space physicist Robert Clauer would trek off to Greenland once or twice a year to gather data on the upper atmosphere. He would fly four or five hours in the back of a cold cargo plane to reach a site where he would sit for days in a trailer crowded with instrument displays. When he wasn't busy observing, he could step outside to admire the aurora borealis or watch a passing herd of caribou. The experience was rugged, and sometimes exhausting, but it satisfied his soul and his scientific curiosity. • Today Clauer does the same kind of research, but he doesn't have to go to Greenland to do it. Rather than travel physically, he is now linked via computers in an experimental "electronic collaboratory" project with other space physicists. The electronic links enable them to initiate experiments from their desktops and study data collected from radar instruments in Greenland, Canada, Norway, and the United States and from space-based satellites. Through chat boxes on per-

let, they may generate more

—such as trust—are hard to develop electronically.

ILLUSTRATION BY RALPH MERCER

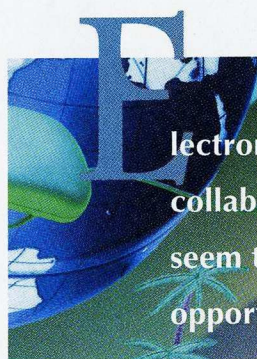
sonal-computer screens, the researchers can put their heads together to interpret data and compare real-time observations to theoretical models generated on supercomputers.

"They are doing something revolutionary in their science," says Gary Olson, a University of Michigan cognitive scientist who helped develop the collaboratory that the space physicists are using.

A collaboratory, as defined by computer scientist William Wulf, who coined the word in 1989, is a "center without walls" in which users can "perform their research without regard to geographical location—interacting with colleagues, accessing instrumentation, sharing data and computational resources, [and] accessing information in digital libraries." Underpinning such a setup is computer software—some designed specifically for the collaboratory and some borrowed from other applications—that enables people at various sites to work on experiments simultaneously. Shared access to electronic notebooks and whiteboards, videoconferencing capabilities, and other such technologies enhance the feeling of being "down the hall while across the country," as James Myers, who leads a collaboratory project in environmental research, puts it.

No one can yet say whether this way of working together is all for the better. Electronic collaboratories do seem to increase opportunities for mentoring; they may raise the frequency and, possibly, the quality of interactions among participants. In some kinds of work, electronic links foster interdisciplinary cooperation, provide access to a wider range of instruments and information, and help narrow the gap between theory and experiments. But something is lost, too, when people interact with instruments and peers from afar. Sitting in front of a computer is no match for traveling to interesting parts of the world, and it's hard to develop trust in people you've met only through electronic channels. What is immediately apparent is that as the future unfolds, ever more people will collaborate electronically.

The first formal discussion of collaboratories occurred at a 1989 National Science Foundation workshop convened by Nobel laureate Joshua Lederberg, president emeritus of Rockefeller University, and Keith Uncapher, senior vice president of the Corporation for National Research Initiatives and dean emeritus of the University of Southern California's College of Engineering. Today, Olson estimates that two dozen or more collaboratories in science, medicine,



**Electronic  
collaboratories  
seem to increase  
opportunities for  
mentoring. They  
may raise the  
frequency and,  
possibly, the quality  
of interactions  
among participants.**

business, and education are under way, in fields ranging from diesel engine design to worm genetics.

Through the Michigan-based Upper Atmospheric Research Collaboratory (UARC), for example, scientists share access to radar and other instruments to study "space weather"—phenomena such as magnetic storms that originate on the sun and can interfere with radio and television reception, disrupt electrical-power transmission, and threaten orbiting spacecraft and astronauts. The Collaboratory for Environmental and Molecular Sciences, based at Pacific Northwest National Laboratory in Richland, Wash., allows scientists in different fields and at many sites to work together on environmental problems, sharing analytical instruments, expertise, and a powerful supercomputer. The Department of

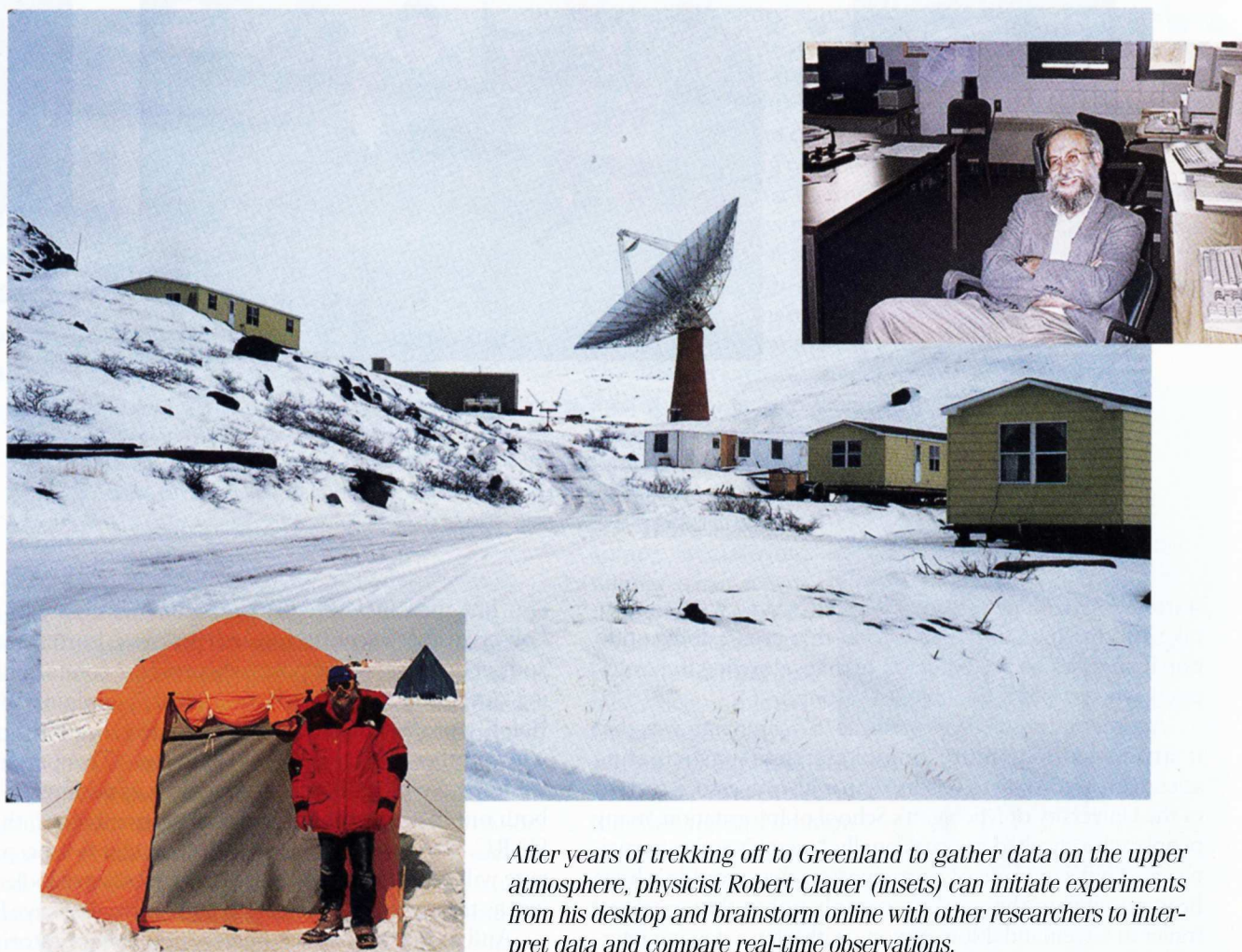
Energy is sponsoring two new collaboratories that will link researchers at government laboratories and universities. One is aimed at designing diesel engines that produce less pollution; the other will explore ways to make corrosion-free materials. Even school kids are logging on to the collaboratory concept. Northwestern University's Collaborative Visualization (CoVis) Project gives kindergarteners through 12th graders in 11 states tools to explore the earth's atmosphere and pick the brains of professional scientists.

The collaboratory has important implications for the corporate world as well. Olson says he has talked to "dozens of companies that are interested in using collaborative technologies to support their work." Finding ways to work effectively with distant colleagues is one of the most important issues today's managers face, he adds: "All of the auto companies, all of the aerospace companies, all of the big hardware and software vendors, all of the telecommunications companies are worrying about this."

## UNEXPECTED BENEFITS

Users are quickly beginning to appreciate what collaboratories can offer. Consider how scientists are benefiting from UARC as it evolves. Originally the space physicists just wanted a way to do more experiments without the expense and disruption of packing up and heading to the Sondrestrom Upper Atmospheric Research Facility in Kangerlussuaq, Greenland. That's what they got. The system's designers arranged for the Sondrestrom instruments to transmit data over the Internet to the researchers, who were also set up with chat boxes on their screens so they could share their reactions to phenomena as they occurred. And the scientists could send instructions to the crew operating the instruments.

*NANCY ROSS-FLANIGAN is a freelance science writer who also works part-time as an information officer in the University of Michigan's News and Information Services office. This article was written and accepted for publication before her affiliation with the university began.*



*After years of trekking off to Greenland to gather data on the upper atmosphere, physicist Robert Clauer (insets) can initiate experiments from his desktop and brainstorm online with other researchers to interpret data and compare real-time observations.*

For the first time, the researchers didn't have to cram their observations into a short visit to Greenland and hope conditions would be right for observations, says Clauer, who's currently on leave from the University of Michigan to direct the National Science Foundation's magnetosphere physics program. Then some space physicists began dreaming bigger dreams. Why not bring more radar instruments online? Tap into satellite data? Make it possible to see the results of computer models and observational data side by side in real time?

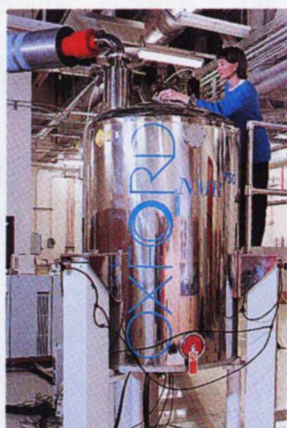
A new version of UARC tested this wish list during two campaigns in October 1996 and April 1997. About 50 researchers worldwide logged on to sample a space-physics smorgasbord. Users could enter various virtual rooms—one for satellite data, another for radar data and models, others for communicating with instrument operators or getting help with software snafus.

The new, improved UARC also enabled the scientists to couple theory and observations better than before. In the April campaign, for example, the scientists used theoretical models to predict what the atmosphere would be doing an

hour later, then compared those with what actually happened. That, says Timothy Killeen, director of the University of Michigan's space-physics research laboratory, was "extraordinary"—the previous time lag was weeks or months.

Moreover, Killeen expects that space physicists will begin scheduling electronic sessions to analyze data and write up results immediately after observing campaigns, which could move the field ahead rapidly by shortening the gap between collecting data and publishing results. "The best papers that are coming out now put multiple data sets together and do comparisons with theory," says Killeen. Given all the contacts necessary among the various scientists, the work involved when a collaboratory isn't used is "a two-year tour de force that exhausts everybody."

Collaborative technology also offers scientists a way to replay interesting observations or experiments. Toward the end of the '97 UARC campaign, a major solar flare sent charged particles toward the earth, creating disturbances in the upper atmosphere—just the kind of thing that makes an atmospheric scientist's heart flutter. The scientists who



*The Collaboratory for Environmental and Molecular Sciences, based at Pacific Northwest National Laboratory in Richland, Wash., allows scientists in different fields and at many sites to work together on environmental problems, sharing analytical instruments, expertise, and a powerful supercomputer.*

started UARC hope to convene an electronic workshop to take another look at the data from that event, doing additional analyses on the data and perhaps drawing in participants who missed it the first time around.

Another intriguing aspect of the '97 campaign was that it attracted even more onlookers than participating scientists. According to Olson, who is also an associate dean of the University of Michigan's School of Information, many people who checked in occasionally "weren't active participants. That's a mode of participation that wouldn't have been possible in the past"—certainly not in that cramped trailer in Greenland. Now, anyone with even a passing interest in the subject can take a peek behind the scenes of a scientific investigation (as long as an electronic firewall isn't set up).

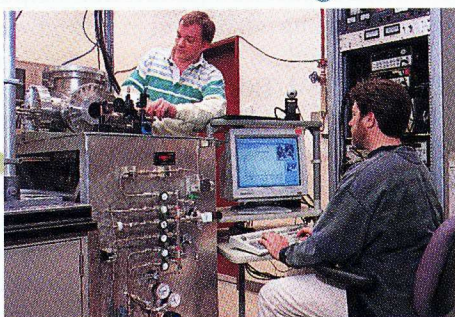
That kind of glimpse could spark a kid's interest in science or help a college student grasp a concept that would be difficult to understand from a classroom lecture. Onlookers from unrelated fields might also offer useful perspectives the space physicists would never think of. Such scenes of broadened communications are playing out in several collaboratories.

For instance, faculty at Northern Michigan University (NMU), a small undergraduate school in Michigan's Upper Peninsula, are looking to a collaboratory to expand their access to instruments and experts that otherwise would be out of reach. Through a joint project with Cornell University funded by the National Science Foundation, NMU is installing an all-sky camera, an instrument that takes pictures of the sky from horizon to horizon. Scientists scan the images for atmospheric glows—the aurora borealis is an example—that are tip-offs to what's happening in the upper atmosphere. The school's location is ideal for such an instrument, but the faculty lack experience in upper-atmospheric research. Through UARC, researchers at other institutions will not only be able to see and study images from the cam-

era, but the NMU faculty and students also will get to "observe other scientists' research practices, learn the jargon, and get ourselves to the point where we are comfortable asking questions and contributing ideas," explains William Ralph, a professor emeritus of physics who heads the project with another physicist, David Donovan. "Then, eventually, we hope we'll be able to do our own experiments, using both our instruments and other instruments that, through UARC, we can operate remotely." Students who participate will get a chance to "see what good science looks like," just as they would at a large research university, says Ralph.

And at major research universities, collaboratories can help less advanced students, report Gary Olson and Tom Finholt, an assistant professor of psychology and director of the University of Michigan's Collaboratory for Research on Electronic Work. They explain that Michigan space-physics graduate students used to do research only in their third or fourth year; with UARC they are jumping into experiments in their first year.

Students and other collaboratory participants are also finding that the setup helps them find mentors in scientists outside their physical institutions. Aaron Ridley, a former student of Bob Clauer, developed such a relationship with Peter Stauning, a senior research scientist at the Danish Meteorological Institute. Ridley, now a postdoctoral researcher at Southwest Research Institute in San Antonio, was an inexperienced grad student in 1993 when UARC was getting under way. During the first experiment he observed, about three weeks after his arrival, Ridley recalls having "no clue to what was going on." That was OK as long as Clauer was available to answer questions; but when Clauer had to teach a class or take care of other business, Ridley was on his own. He began soliciting advice from Stauning, a constant presence in the collaboratory. Before long, "Peter was kind of like an uncle," Ridley says, "who shows you the way."



Mentoring is also a key part of Northwestern's CoVis project for K-12 students. Faculty and students from the atmospheric sciences department at the University of Illinois at Urbana-Champaign offer advice and expertise to individual students or whole classrooms. As might be expected, some kids don't seem to appreciate the offer until the night before a project is due. But others strike up long-term friendships, grilling their mentors on everything from cloud colors and snowfall totals to more personal information, such as age and marital status. "They like getting the quick responses—being able to come up with questions and get answers delivered right to them," says CoVis coordinator and mentor Steven Hall.

And at the other end of the knowledge spectrum, at least one collaboratory has been set up to help experts find assistance in areas unfamiliar to them. The aim of the Collaboratory for Environmental and Molecular Sciences is to help researchers in different fields work together on the cleanup of radioactive and chemical waste at the Hanford site, a contaminated site in southeastern Washington that covers an area more than half the size of Rhode Island. "What we would really like to do is have some mass spectroscopists and modelers and theoretical chemists work with an engineer who can take that knowledge and turn it into a technology and then work with somebody on the site who's actually going to use it," says James Myers, project leader for the Collaboratory for Environmental and Molecular Sciences. "If we don't happen to have an expert in a certain area, we can go to a university and get one and plug [that person] into the team. It allows us to think more broadly in terms of what we can propose to do."

## BYTES EQUAL MORE IDEAS

Evidence for the communication power of electronic collaboratories comes not just from users but also from behav-

ioral scientists such as Finholt and Olson who are peeking over collaborators' shoulders, eavesdropping on their electronic and face-to-face conversations, and analyzing everything from publication patterns to the development of mentoring relationships. They share their observations with programmers who can then integrate changes into the technology underlying collaboratories.

One of the first questions Finholt and Olson asked the programmers was whether collaboratory users talk about the same things in online conversations as they do face to face. They do. "On the whole, when something interesting in the science happens, that's what dominates the conversation, just as it does in face-to-face conversations," says Olson. "And similarly, when things are quiet, you find some socializing, talking about schedules, the same kinds of things [scientists] talk about face to face when nothing is happening." Conversations about families, books, news events, and the like are as common over the electronic channels as across the lab bench.

Electronic collaborators are more likely to share ideas, however. "When groups use computer-mediated communication in brainstorming tasks, they outperform face-to-face groups in terms of the number of ideas generated and, according to some studies, the quality of ideas," Finholt says. He's not sure why that occurs. Perhaps, he speculates, "it has something to do with seeing the ideas on a screen—that they're more visceral or more real."

Or the reason could lie in the fact that collaboratory participants take care to compose their thoughts and think their ideas through before broadcasting them, suggests Olson. Face to face, people are more likely to blurt out short statements, sometimes without carefully considering what they're about to say. Although people sometimes send hasty, rash messages by e-mail—as any user of the medium can attest—research shows that such comments are actually less common than in face-to-face encounters. In an electronic exchange, the average contribution is longer, more complex, and more carefully developed.

Another possibility is that the usual cues that communi-

**N**ow, anyone with even a passing interest can take a peek behind the scenes of a scientific investigation. That kind of glimpse could spark a kid's interest in science.



*Behavioral scientists Gary Olson and Tom Finholt study the effectiveness of electronic collaboratories by eavesdropping on the collaborators' electronic and face-to-face conversations and analyzing everything from publication patterns to the development of mentoring relationships.*

cate status are absent and everyone feels free to contribute. Such status cues do seem to interfere with face-to-face interactions among medical specialists, one of Finholt's students, Stephane Cote, has found. According to Cote, face-to-face communication between radiologists and clinicians is often hampered by differences in "identity functions"—the mores and ideals that lead to a sense of professional identity.

"The clinician is primarily oriented toward curing the patient," explains Finholt. "The radiologist has that as a high-level abstract goal, but is mainly interested in rendering the most precise and accurate interpretation of a particular image. Conflict arises when the radiologist is reluctant to speculate beyond the bounds of what he or she sees, to help the clinician determine what the course of treatment ought to be. To the clinician, it looks like the radiologist is stonewalling or somehow not coming clean." To add to the problem, these discussions usually take place on the radiologist's turf, where the clinician is an outsider. Rather than focusing on what they're discussing, the two specialists often try to reinforce their importance by making cutting remarks about each other's areas of ignorance, Cote has observed.

Cote and Finholt believe a medical collaboratory recently begun at their school may lessen such tension. Looking at x-ray and ultrasound images on a computer screen, a radiologist can use an on-screen pointer and record oral notes to indicate areas of interest. The clinician can later call up the images on a computer in a clinic and replay the radiologist's remarks, following the pointer to see the exact area being described. The two physicians can exchange comments, questions, and clarifications as often as necessary

without venturing into each other's physical territory.

Although the system is too new for Finholt and Cote to draw conclusions about its use, they suspect it will help the different parties focus on solving patients' problems. "It would be an interesting paradox," says Finholt, if "the elimination of face-to-face communication helped them talk better."

## E-MAIL DOESN'T EQUAL TRUST

Despite such attractions, behavioral scientists and others recognize that electronic collaboratories have some downsides. For instance, even the best collaborative technologies seem to be poor substitutes for a handshake and eye contact. Eleana Rocco, a visiting researcher at the University of Michigan from the University of Venice, is comparing the formation of trust in groups that communicate only electronically with ones that have met in person. Rocco has had groups of subjects play an electronic game that involves both cooperation and competition. Some groups met face-to-face for 5 to 10 minutes before playing the game; others met only virtually. The groups that had face-to-face contact showed much more cooperation than the others.

"In this kind of task, cooperation arises from confidence and trust in your colleagues," says Gary Olson. "It's clear from this research that [trust] requires face-to-face contact. It doesn't have to be a lot, but groups who only have electronic contact never form trust in the same way that groups who have some face-to-face time do."

Ford Motor Company learned that lesson the hard way. As part of its plan to reorganize the company by functional rather than geographic groups, Ford tried to use collaborative technology to build international teams. Olson's group studied one team that communicated almost exclusively through videoconferencing, e-mail, and other electronic means. "After a year, that group had never really become a group," he says. "It was clear that as time went on, the characteristics of communication among those in the same physical location were quite different from [the group] with people at remote sites."

Now the company has taken another approach, Olson says. While still using collaborative technologies, it has teams work together initially. That seems to be helping. "There certainly are teams that have face-to-face experience and still have trouble—it's not a guarantee of success," points out Olson, "but it does seem to help with the process of team formation."

A shared sense of trust and identity could explain why space physicists have embraced the collaboratory concept while researchers in less cohesive fields have been slower to come on board. With a long tradition of sharing instruments and data and a clear consensus on such matters as ownership of research results, the small group of space physicists who used the original version of UARC was strong on international collaboration from the start. They had worked together to develop "rules of the road" and had

put those into writing. They simply had to modify these rules slightly to fit the electronic forum. But when Olson met with a group of neurophysiologists, geneticists, epidemiologists, and clinicians who wanted to form a collaboratory to study mood disorders, he found a different world.

"These fields all have very different traditions about who owns data, who gets rights to data, and so on," he explains. Even within each discipline, the traditions were established informally, not by explicit consensus. Before they can begin to collaborate, these groups will have to agree on ground rules—a process that will no doubt require face-to-face meetings and could take considerable time and effort.

Another potential problem with electronic collaboratories is that high-powered researchers and engineers may become so swamped with requests that they flee from this mode of communication and so turn collaboratories into a sort of scientific ghetto. In a January 1997 paper in the journal *Psychological Science*, Finholt and Olson cite research showing that elite scientists using forms of electronic communication such as e-mail are more likely than their nonelite counterparts to receive messages—but also more likely to ignore them, especially when they come from nonelite researchers.

Of course, the busier the researcher, the more apt he or she is to receive messages of any kind. And scientific snobbery existed long before collaboratories came on the scene. The question is whether the technology makes the problem better or worse. While the answer isn't in yet, Olson suggests that elitism isn't the only factor to consider. Some driven researchers may keep their distance from collaboratories because they will not want to take time out to learn how to use the new technology. In competitive fields such as high-energy physics and molecular biology, "there are Nobel Prizes at stake," he says. "Anything that would slow you down or interrupt your work is a real big risk." That, in turn, could make more junior scientists wonder, "Should I waste my time learning all this stuff while they're off earning their Nobel Prizes, or should I get cracking in the laboratory?"

Olson believes that they can do both. Because most younger researchers are more comfortable using computers, they don't have to invest as much time learning to use collaborative technology as the most notable and generally older people in a field do. The younger workers should quickly find that the technology can speed rather than impede their progress.

But this raises another question: Could students and junior researchers end up relying too heavily on electronic collaboratories? Basking in the glow of a computer screen is not the same thing as experiencing an aurora borealis firsthand. Robert Clauer laments that his former student Aaron Ridley completed his graduate degree without ever making the trek to Greenland in the back of a cold, dark cargo plane or stepping outside the trailer to see the aurora. Clauer notes that collaboratories may make for good science, "but it's better for the soul to be there." And on a

practical level, the arduous experience has long been an important part of a young researcher's education in understanding where data come from and what's involved in keeping instruments running.

Ridley admits he missed out a little. His research experience, he says, was "like driving a car in a video game, versus driving a real car."

Neither newly minted scientists and engineers nor graybeards are likely to see electronic collaboratories as a real alternative to traditional ways of working unless they can be confident that the underlying technology is reliable. Even collaboratory enthusiasts admit that, with collaboratories still in experimental stages, that isn't always so. Screen displays change; tools such as sticky notes and other annotation doodads are added and then taken away if they prove unwieldy or unpopular. Such moves unsettle people accustomed to using instruments that look and perform the same way day after day.

Much of the problem is not with the collaborative software but with the Internet. For instance, Olson admits that Internet congestion has seriously interfered with UARC's performance. But the situation could improve dramatically with the coming of Internet2, a high-speed computer network dedicated to research and education applications that more than 100 universities are building.

How will electronic collaborations fit into the future of the laboratory, classroom, and workplace? The answer will depend on the creativity of those who design and use them. No one is suggesting that the new approach should completely replace traditional ways of working together. Meetings, workshops—even a limb-numbing plane ride to Greenland and the awesome sight of an aurora—will continue to have their place. Just as scientists often must juggle variables to figure out models that best describe what's happening, collaborating groups must keep tweaking the equation to find the right balance of face-to-face discussions, hands-on work, and electronic communication. The results should be new ways of working that raise productivity, foster creativity, break down barriers while building trust—and still manage to satisfy the soul. ■



**B**asking in the glow of a computer screen is not the same thing as experiencing an aurora borealis firsthand.



VISIT OUR WEB SITE FOR RELATED INFORMATION:  
<http://web.mit.edu/techreview/>

## MEDICINE ON THE WEB Finding the Wheat, Leaving the Chaff



**A** family recently came into my office and dumped a foot-high stack of papers on my desk. These, they explained, were pages they had printed from the World Wide Web that provided information on their child's rare genetic disease. What did I, a doctor and expert in the field, make of the reports? That night I spent eight hours reading through the pile, trying to separate quackery from relevant information. During that long evening, I also realized the extent of the difficulties ever more people face when they are trying to make important decisions about health care options.

Over the last few years the Internet has started to create an amazing challenge for medical providers. When people receive an unusual diagnosis, they frequently go to the Web to obtain all the information they can find. Every doctor I know has at least one anecdote about patients coming in with mounds of Web pages.

The problem is that many patients and their families often don't have a way

**If you've recently had a medical problem, chances are that you have used the World Wide Web as a kind of Physician's Desk Reference. Watch out: there's an awful lot of electronic nonsense floating around cyberspace.**

to discriminate between the substance and junk served up on Web pages and chat lines. And as Robert W. Cooke, a science writer at *Newsday* in Long Island, has pointed out, some of the junk may be particularly appealing because it is written much more clearly than scientific papers. So the idea that what is actually hokum might help can seem especially attractive when controlled, peer-reviewed studies do not offer much hope for a serious disease.

Sometimes decisions based on poor information gleaned from the Web prove devastating. Diana W. Bianchi, chief of genetics and perinatal genetics at New England Medical Center in Boston, has spoken of several couples who decided to abort a pregnancy based on what they read on the Web about a problem such as mental retardation that they thought their child could end up with. Yet the condition their doctors actually identified was only rarely associated with a functional difficulty. She reports that these

couples were so firm in their decisions that they did not want to listen to or even consult a genetic counselor who could explain the true risks involved.

Fortunately, some members of the public appreciate the value of scientific papers over other kinds of information. Occasionally patients with rare conditions arrive at a clinic having correctly diagnosed themselves based on their Web research. John A. Phillips III, a professor of pediatrics and biochemistry at Vanderbilt University School of Medicine in Nashville, has encountered families who recognized a disease their physicians did not.

Still, most people who use the Web to obtain medical information do not know if what they are reading is sensible. This means that their clinicians can face a strange kind of liability. Many doctors, with their days already stretched by the changes in the health care system, simply can't read everything given to them by their patients. But if we don't do so, our patients may end up with misconceptions and/or lose their trust in traditional medicine based on scientific studies.

Perhaps the most useful way to help patients and their families obtain a handle on the legitimacy of what they're reading on the Web is to establish a publicly acceptable method of grading information (sort of a "V" chip reflecting authenticity). To best accomplish this, a group concerned with patient welfare could bring together consumers, Internet providers, the medical establishment, support organizations interested in particular disorders, and the public to organize such a system. The group could, say, recommend measures such as dating information so readers can recognize if it has undergone appropriate review and revision.

This past fall the *Boston Globe* reported that several organizations have already started to develop variations along these lines. For example, officials with the American Medical Association have published "core standards" consumers can use to consider the relative value of online health information, and the Health on the Net Foundation in

Geneva has created a logo for medical Web sites that include "principles" set forth by that organization. This coming spring the Health Information Technology Institute (HITI)—which is associated with Mitretek, a nonprofit environmental and engineering-technology organization of McLean, Va.—plans to publicly offer medical-information "quality" criteria. HITI has spent the past year organizing the group developing the criteria so that it has the kinds of constituents I'm suggesting; the group's members range from doctors to consumer representatives.

Physicians and researchers need to recognize that since the public now has easy access to their literature, clarity is a virtue. Moreover, papers that lay readers can understand may help provide something of a bridge to those people who mistrust doctors because we want treatments to undergo proper scientific review and insist on or at least try to provide evidence-based medicine. Doctors would also do well to make the effort to refer individuals and families with serious or rare conditions to appropriate lay support groups that usually offer the benefits of collective experience and good sources of information—which can include Web sites.

The information revolution has compounded the complexity of doctor-patient relationships. The Internet has essentially enabled patients and families to easily seek second opinions, and third ones, and more. Given two provisos, this can produce benefits for both concerned patients and busy medical practitioners, who presumably want the best outcomes for their patients. Laypeople must have the means to understand and evaluate the strength and validity of the information they obtain. At the same time, they should not expect their doctors to have the luxury of time or economy of practice to "surf" with them. ■

*JUDITH G. HALL is a pediatric geneticist and head of the Department of Pediatrics at British Columbia's Children's Hospital and University of British Columbia.*

# Computer Camp

@

MIT•Stanford•Georgetown

20 LOCATIONS NATIONWIDE



**American  
Computer  
Experience**

•Coed ages 7-16

•Programming in Basic, C, C++

•Day & Overnight camps

•Web design-HTML, Java

•Network games & Sports

•Beginners to advanced

•PC & Mac platforms



**1-800-FUN-4ACE**

[www.computercamp.com](http://www.computercamp.com)

[ace@computercamp.com](mailto:ace@computercamp.com)

## TRAINING ON WORLD-CLASS R&D MANAGEMENT

The Center on Business and Technology Strategy of Northwestern University/Evanston Research Park has provided training for **128 companies** in Canada, China, Germany, and the United States. The training is provided at the company site for 15 to 30 people. Based on interviews at 600 companies, **over 400 examples** of world-class practices in R&D management are provided.

Some of the **14 topics** are:

- ✓ Selecting R&D
- ✓ Managing project teams
- ✓ Motivating R&D people
- ✓ Measuring R&D
- ✓ Coordinating R&D and business planning

For more information,  
call (847) 869-0676  
or write to:

Dr. Robert Szakonyi  
Director, Center on Business and  
Technology Strategy  
Northwestern University/Evanston  
Research Park  
1840 Oak Avenue  
Evanston, IL 60201 USA

ARE we all agreed, then, that technological change is the true destiny of the human species? As I read the books and articles heralding the new millennium, there seems almost uniform consensus that the twenty-first century will be characterized exclusively by technical advances and the quick adaptation of society to their requirements. If there are other sources of hope and renewal in the works, we seem less and less able to imagine them.

Most remarkable about these technology-centered visions of the future is their use of outmoded language of inevitability. Commentators speak straight-faced about ineluctable forces, historical laws, and irrevocable impacts, employing imagery reminiscent of late nineteenth century romanticism. In his book *The Future of Capitalism*, for example, Lester Thurow depicts technological change as a "tectonic force" that we must obey but can never hope to master. The best we can do, Thurow says, is to read these forces and position ourselves for maximum advantage. In a similar vein, *Wired* magazine editor Kevin Kelly enlightens us with a list of twelve "laws" for the era of digital electronics—laws that he says are bringing "an upheaval in our commonwealth, a social shift that re-orders our lives."

In reports about specific kinds of technical development, proclamations of inevitability often lapse into fatalism. The weekly news magazines have told their readers about how workplace surveillance, online monitoring, and electronic networks generate data trails that erode our privacy. While these stories sometimes offer advice on how to protect the security of personal information, they typically assume that privacy-destroying electronics are so deeply entrenched that systematic remedies are impossible. In "No Place to Hide," a report in *Forbes* on the tracking devices that surround people's every move, Ann Marsh agonizes that new information systems may "bring on Orwell's 1984, making us all slaves of the state." Does this mean we'll need new legislation and stronger citizen action to counter this threat? Not at all. Marsh concludes that

# Prophets of Inevitability

*Contrary to  
millennial hype,  
human choice—not  
immutable forces of  
nature—governs the  
development and adoption  
of technologies.*



LANGDON WINNER

"the damned thing is practically here. Let the chips fall where they may."

The irony here is that among historians and sociologists who study the interactions of technology and society, ideas about necessity and inevitability are now considered laughable. A careful examination of how emerging technologies develop reveals not "forces" or "laws," but instead a panoply of social, cultural, and political choices. Technological change is a sphere of contingency, negotiation, and conflict in which nothing is historically necessary.

From the shaping of vast systems in telecommunications to the design of minute features on an emerging microchip, one always finds the shaping hand of engineers, corporate planners, and social interests with a stake in particular outcomes. The reason our household refrigerators use electric motors rather than burn natural gas, for example, stems not from the "inevitability" of electricity but from the influence of the electric power industry over consumer choices decades ago.

Why, then, do predictions of a technological inevitability now have such strong popular appeal? For the techno-prophets, the incentives are obvious. Like ancient seers and soothsayers, they can claim special knowledge of the future, advising a benighted public on where things are headed, raking in handsome lecture fees and book contracts in the process. What ordinary folks derive from these future visions is the comfort of believing that the future has already been scripted and that (if they scramble fast enough) they can find agreeable parts in the drama.

But those who herald a technologically driven future are, in effect, advising we give up our role in choices about which technologies are chosen and why. Suggested instead is the Rip Van Winkle approach: just go to sleep and we (the anointed) will wake you when it's over.

For now, the energetic sales pitch for Van Winkle-ism appears to be working. Large segments of the population apparently believe that innovations simply pour from a bubbling volcano, giving shape to new ways of living as the lava cools. The danger is that people who ought to be engaged in deciding how to use technology in schools, clinics, workplaces, and homes will abdicate their civic responsibility. Why, these people might wonder, should they waste their energy fighting the inevitable?

In this manner, there is a powerful "law" that could well govern developments in years to come—the law of self-fulfilling prophecy. If everyone thinks technological trends are inescapable, they probably will become so. That is why those serious about the human prospect should reject the rhetoric of fatalism and demand something more substantial. When we hear pompous blather about "laws" and "forces," we owe it to ourselves to interrupt, and steer the conversation toward a different vocabulary—one encompassing terms like "alternatives" and "choices." ■

LANGDON WINNER teaches science and technology studies at Rensselaer Polytechnic Institute. He can be reached at [winner@rpi.edu](mailto:winner@rpi.edu) and through his Web page, [www.rpi.edu/~winner](http://www.rpi.edu/~winner).

# Reviews

## SOFTWARE

### SETTING A STANDARD IN MULTIMEDIA SOFTWARE

*Volcanoes: Life on the Edge; Critical Mass: America's Race to Build the Atomic Bomb; and Leonardo da Vinci*  
Corbis Corp., \$49.95 per title

BY WADE ROUSH

As multimedia and networked computers invade the traditional turf of newspapers, magazines, the broadcast media, and the venerable book, writers such as myself take consolation in one thought: that as the means of conveying content multiply, so will the need for effective "content providers." Yet the sameness of the multimedia software filling the shelves



*Volcanoes* contains not only maps and diagrams of volcanic activity, but also vibrant, stunning images of volcanoes in action.

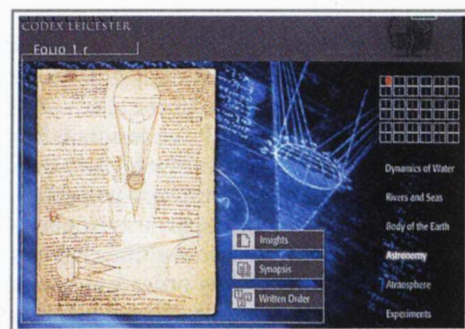
of most computer outlets today raises doubt about whether there is, or will ever be, significant demand for original multimedia content. New-Age puzzle games such as *Myst* and *Qin* and slash-and-burn combat simulations (*Doom*, *Quake*, and *Duke Nukem* come to mind) seem to take up the most shelf space, followed by reference works such as Microsoft's *Encarta* and *Cinemania* that exploit the sheer storage capacity of a CD-ROM without adding much in

the way of interactivity or graphical elegance. Just as in commercial television, the medium's vast possibilities—at least for now—go largely unexploited.

Yet one company has recently restored some of my optimism. Over the last year and a half, Corbis Corp. has introduced a line of educational/entertainment CD-ROMs whose rich content and sophisticated style put most other multimedia software to shame. Devoted to virtually inexhaustible subjects such as Leonardo da Vinci, Paul Cezanne, Franklin D. Roosevelt, and the Manhattan Project, the discs show how the skillful use of technology can enhance—rather than simply transmit—the meaning in archival and contemporary visual and audio material. The programs outshine other software in much the same way that the best PBS programming, such as *Nova*, *The American Experience*, and filmmaker Ken Burns's *The Civil War*—highlights the intellectual poverty of most commercial TV.

Corbis Corp., set up in 1989 by Microsoft founder Bill Gates, is mainly an electronic archive that owns and licenses the rights to digital representations of millions of photographs and paintings, including famous collections such as the former Bettman Archive. This may sound like a surprising source for high-brow educational software. But Corbis's own images are at the core of its CD-ROM titles, and it was shrewd of the company to hire a top-notch team of producers to prove that its copyrighted archives can be recycled as great multimedia entertainment.

All six of Corbis's current CD-ROM titles, available in Windows '95 and Macintosh formats, are worth the investment. Here I'll comment only on those titles related to science and technology: *Volcanoes: Life on the Edge; Critical Mass: America's Race to Build the Atomic Bomb*; and *Leonardo da Vinci*. Of the three, *Volcanoes* is the most conventional, but also, in a way, the most arresting. The program revolves around award-winning science photojournalist Richard Ressmeyer's 14-month assignment in 1991 and 1992



The entire Codex Leicester, da Vinci's notebook on the behavior of water, is one of the many highlights of Corbis's CD-ROM *Leonardo da Vinci*.

to photograph dormant and active volcanoes—and the human cultures that alternately thrive and cower beneath them—for *National Geographic* magazine. The hundreds of stark, beautiful photographs by Ressmeyer, reproduced here in remarkably vivid color and high resolution, are illuminated by a lean, poetic script—narrated by British actress Helen Mirren—that recalls the spare yet information-dense photo captions in *National Geographic*. Dozens of "episodes" dot the point-and-click map of the globe at the program's core, detailing past disasters, such as the entombment of 23,000 Colombians in 1985 under a mud flow from the Nevado del Ruiz volcano, and disasters waiting to happen, for example the eruption prefigured by the present-day resurgence of the caldera beneath California's Long Valley resort area, the site of an apocalyptic eruption some 760,000 years ago. Also retold are Ressmeyer's own scary moments, such as the time he and a guide were nearly trapped on Italy's Mt. Etna by a wayward river of lava.

At any point in an episode, the user can pause the narration to examine an image at leisure, use the extensive glossary to investigate obscure volcanological terms like "lahar" (volcanic mudflows that can travel as fast as 100 mph) or "aa" (crusty, slow-moving lava), or read about the history, physical characteristics, and death tallies of notorious volcanoes such as Krakatau and Tambora (the latter's 1815 eruption killed 92,000). For users more interested in

Ressmeyer's images than in the program's bells and whistles, a slide-show function cycles through the disc's 480 photographs. Overall, the program has the feel of a visual voyage of the HMS Beagle—part science lesson, part anthropological expedition, part travelogue—but with the difference that the chapters can be explored in any order and to any desired depth, so that delving into the program is like editing one's own nature documentary. A rumbling piano score, Mirren's breathlessly grim narration, and Ressmeyer's own reflections on the grueling assignment foster an appropriate mix of dread and reverence for these spectacles of nature.

If *Volcanoes*'s scope is panoramic, *Critical Mass* is deliberately claustrophobic. The disc's opening sequence sets the tone by recreating the dark, drizzly

conditions near Alamogordo, New Mexico, in the wee hours of July 16, 1945—a gloom that soon gave way to nuclear morning. After viewing a newsreel-style overview of the political crisis that drove the nation's top physicists to unleash the horrific power of the bomb, the user is deposited in a small office, cluttered with papers, folders, and filing cabinets, that serves as the graphical gateway to the other parts of the program. Though a bit hokey—probably consciously so—the office lends a tangible sense of depth to the program, as if one were actually stepping into the past.

Behind a desk in the office, in fact, are cutouts of a grandfatherly Niels Bohr, the perpetually abstracted Robert Oppenheimer, a congenial Enrico Fermi, and a brash young Richard Feynman. Clicking on any of these great physicists or others represented in portraits and newspaper clippings launches biographical slide shows full of personal detail. Beyond a window in the office a slice of Los Alamos is visible, leading to the program's most remarkable feature: a digital rendering of the top-secret installation as it appeared on a sunny day in 1945. From seven standpoints along the dusty roads lacing through the facility—known to the outside world only as P.O. Box 1663, Santa Fe, New Mexico—the visitor can pan 360 degrees to view the fenced-in town's labs, machine shops, hut-like residences, dining and lecture halls, and other hastily erected structures. Clicking on highlighted buildings calls up interior shots and commentary from Roger Mead, archivist of the current-day Los Alamos National Laboratory. Sound effects, from clanky cafeteria hubbub to click-clacking adding machines and tremulous big band saxophones, serve as reminders that this was a bustling place where, at the height of the bomb-building effort, some 6,000 people lived and worked.

Rounding out the program are a detailed timeline, an illustrated scientific glossary, an archive of declassified Manhattan Project documents, a collection of nuclear-age images and animation



*Critical Mass* takes users on a stimulating tour of Los Alamos where they can learn what went into the making of the first atomic bomb.

(including the classic civil defense cartoon "Duck and Cover"), and an "atomic atlas" mapping the nuclear detonations, atomic power plants, uranium deposits, and reactor accidents of the 20th century. Much of this material is available elsewhere, and no one who has read histories such as Richard Rhodes's *The Making of the Atomic Bomb* will find much that's original, surprising, or even critical in *Critical Mass*. What will delight atomic aficionados, historians of science, and the uninitiated lay user alike, however, is the way the program turns 1940s Los Alamos, the almost mythical crucible of our Cold-War obsessions, back into a tangible, gritty, even familiar-looking place.

Unlike *Critical Mass*, *Leonardo da Vinci* is built around a historical source hitherto unavailable, at least to everyone but Leonardo scholars and billionaires: the Codex Leicester. The Codex, an intricately illustrated notebook created between 1508 and 1513, was Leonardo's study for an unrealized treatise on the behavior of water. Bill Gates purchased the Codex from Armand Hammer in 1994, and the Corbis CD-ROM reproduces all 72 pages so realistically that it almost feels as if one were handling the original parchment. Corbis's look at "the original Renaissance man" is both the company's best CD-ROM to date and the hardest to do justice to in print.

Of course, a Leonardo notebook wouldn't make much sense to anyone unschooled in reading Leonardo's pecu-

## TECHNOLOGY REVIEW

### SUBSCRIBER SERVICES

If you ever have a question or problem, just send your mailing label with a brief note to the address below.

**IF YOU'RE MOVING:** Please give us four weeks notice. Attach your label and fill in your new address.

**IF YOU'RE SUBSCRIBING OR RENEWING:** Check the appropriate box below and fill in your name and address. Send with your payment of \$29.70 per year. (Canada add \$6. Other foreign countries add \$12.) Payment must be in U.S. funds drawn on a U.S. bank.

**IF YOU WANT TO BE UNLISTED:** Occasionally we make our mailing list available to other quality publications or organizations. If you prefer to have your name removed from the list, please attach your label and check the appropriate box below.

**TO GIVE A GIFT SUBSCRIPTION:** Send both the name and address of the recipient and your name and address.

- |   |   |
|---|---|
| <input type="checkbox"/> NEW SUBSCRIPTION             | <input type="checkbox"/> PAYMENT ENCLOSED |
| <input type="checkbox"/> RENEWAL                      | <input type="checkbox"/> BILL ME LATER    |
| <input type="checkbox"/> PLEASE UNLIST MY NAME        | <input type="checkbox"/> GIFT             |
| <input type="checkbox"/> PLEASE CHANGE MY ADDRESS TO: |   |

NAME \_\_\_\_\_

ADDRESS \_\_\_\_\_

CITY/STATE/ZIP \_\_\_\_\_

MAIL TO  
TECHNOLOGY REVIEW

P.O. BOX 489, MOUNT MORRIS, IL 61054  
OR CALL 1-800-877-5230

or e-mail <trsubscriptions@mit.edu>

## BOOKS

## THE DANGER OF EXPECTATIONS

*Space and the American Imagination*  
by Howard E. McCurdy  
Smithsonian Institution Press, \$29.95

BY NORMAN WEINSTEIN

liar mirror-image 15th-century Italian. A delightful Corbis invention called the Codescope, however, begins to make the penetrating observations of this painter-engineer-inventor accessible. The Codescope is, in effect, a magical magnifying glass that, when placed over Leonardo's original script, flips it around so that it reads from left to right. It also overlays a transcription of the Italian text in legible Roman characters or converts the Italian transcription into modern-day English. Even with all that help, though, following the arguments in the Codex can be tricky. While Leonardo's reasoning about the nature of turbulence, the existence of water on the surface of the moon, or the origins of rivers is impeccably logical, it proceeds from a pre-Newtonian view of nature so distant from our own as to make Leonardo's conclusions seem, at times, ludicrous. He argues, for example, that the water in a lake or river imposes no weight on the ground beneath, "as shown by the thin grass waving through water at the bottom . . . which has almost the lightness of water itself; instead, had the water gravity over it, it would be compressed and almost petrified."

Of course, it's not what Leonardo concluded but the way he thought about the world that makes him one of modernity's most important progenitors, and that's what the Corbis program really brings to life. Interpretive remarks by Leonardo scholars, multimedia "tours" and "exhibits" on the Codex's main themes (including animated versions of some of Leonardo's illustrations and experiments), a detailed timeline of the Renaissance, and a virtual art gallery add to the central Codex. They also show how Leonardo repeatedly returned to themes such as flow, whether it be that of a river or a lock of hair. I, for one, had never before noticed the backdrop of tiny lakes, rivers, and bridges behind the Mona Lisa. Content providers as effective as Corbis, it's clear, need never fear a change of medium. ■

WADE ROUSH writes for *Science* magazine.

SINCE its beginnings, the U.S. space program has been motivated by a highly romantic dream," writes Howard E. McCurdy, a professor of public affairs at American University, in the introduction to his latest book, *Space and the American Imagination*. With its engaging cover and the author's promise to examine how "the rise of the U.S. space program was due in part to a concerted effort by writers of popular science and science fiction," the book seems to offer readers a study of how fantastic space imagery has affected space policy and NASA's direction. However, instead of discussing the positive influence of space imagery, McCurdy uses examples culled from science fiction novels, magazine illustrations, film, and television, to criticize the image-makers for creating impossible-to-fulfill fantasies that politicians and NASA can never realize.

The author has zeroed in on some of this terrain before; NASA was the subject of McCurdy's two earlier books, *Inside NASA: High Technology and Organizational Change in the U.S. Space Program* and *The Space Station Decision: Incremental Politics and Technological Choice*. The twist offered here is a "cultural studies" emphasis in place of the sociopolitical exegesis offered in those earlier studies.

Although McCurdy admits that "works of imagination dealing with space exploration are among

the most entertaining in American culture," his affection is tempered by the sense that such material muddies the public debate about space exploration. For example, McCurdy describes how President Dwight D. Eisenhower was primarily interested in channeling NASA's activities toward unmanned space probes, a proclivity that was overturned when Sputnik was launched. The public hysteria about "catching up" to our Cold War enemy, from the author's perspective, played into the hands of NASA officials seeking funding for manned missions. Suddenly the issue of Americans in space was transformed into a national security issue as well as a manifest-destiny dream.

McCurdy criticizes the manipulation of public opinion through outrageous cultural images suggesting that America faced nuclear annihilation if it let the former Soviet Union maintain the upper-hand in space exploration. It was as if media coverage of Sputnik opened a Pandora's box in the national psyche. He highlights Chesley Bonestell's illustration of an atomic attack on New



# Classifieds

## TEACH IN JAPAN

Individuals with university degree(s) & professional experience in science, engineering and technology needed to teach in their fields and business English in Tokyo and Osaka. Please forward resume to:

### International Education Services

Rose Hikawa Building  
22-14, Higashi 2-Chome  
Shibuya-Ku, Tokyo 150  
Fax: 81-3-3498-7113  
e-mail: iesinfo@iac.co.jp

A new engine technology patented in 1987.

"Elements of FRASCA  
ROTARY ENGINE DESIGN"

\$14 + S&H Available at:  
[WWW.AMAZON.COM](http://WWW.AMAZON.COM)

## SPORTS START-UP

Fun group of MIT alums have fully funded start-up whose product will revolutionize the way sports are broadcast and coached. Trakus, Inc. seeks digital hardware engineers, microwave engineers, and C++ programmers to join the team.

If your looking for a great environment, good pay and lots of growth opportunity visit our website at [www.trakus.com](http://www.trakus.com) or fax resume to 617-623 4505.

## COMMERCIALIZE YOUR TECHNOLOGY, PROCESS, PRODUCT

Launching technologies requires superior, up-to-date information, so that you can make good decisions and take effective actions. We meet broad and specific marketing and business development needs for small to large companies. Boston-area, with a world wide client base.

*Specializing in launching technology, science, and engineering products and processes for diverse markets.*

MONTAGUE ASSOCIATES - (978) 927-2082; F: 921-1627

## NEW AUTHORS

### PUBLISH YOUR WORK

ALL SUBJECTS CONSIDERED  
Fiction, Biography, Religious, Poetry, Children's.

AUTHORS WORLDWIDE INVITED.

WRITE OR SEND YOUR MANUSCRIPT TO

**MINERVA PRESS**

2 OLD BROMPTON ROAD, LONDON SW7 3DQ, ENGLAND

## SINGLES IN SCIENCE

and others interested in science/nature are meeting through *Science Connection*

1-800-667-5179; [sciconnect@compuserve.com](mailto:sciconnect@compuserve.com)  
On-line registration: [www.sciconnect.com/](http://www.sciconnect.com/)

## Date someone in your own league.

Graduates and faculty of MIT, the Ivies and Seven Sisters meet alumni and academics.

**The Right Stuff.**

1-800-988-5288



We Need More  
Trees

Trees Make a World of Difference. Trees make our cities and neighborhoods more liveable. They create quiet places to enjoy, give wildlife a home, and increase property values.

This year, plant Trees for America. For your free brochure, write: Trees for America, The National Arbor Day Foundation, Nebraska City, NE 68410.



**The National  
Arbor Day Foundation™**  
[www.arborday.org](http://www.arborday.org)

## REVIEWS

York City, which the former Soviet Union supposedly could initiate from the moon. The visual accompanied an article in *Collier's* entitled "Rocket Blitz from the Moon."

From its third chapter, which describes Sputnik's impact, to its conclusion, McCurdy's book takes a curious turn: It sheds the trappings of an academic study and becomes a sermon attacking the unsavory aspects of romantic imagination pertaining to space.

The list of sinister figures accused of "inflaming" the public imagination to expect unrealistic miracles from NASA evokes the methods of Senator Joseph McCarthy. McCurdy scapegoats everyone from science fiction novelists (Arthur C. Clarke and Carl Sagan are among the best known targets) to NASA "visionaries" (not a flattering term in McCurdy's world) like Werner von Braun. Even classic fantasy authors like Jules Verne and H.G. Wells come in for their share of criticism. Their crime? McCurdy concludes his book with this damning accusation: "Works of imagination have become so pervasive in American culture that the latitude of the government to satisfy them grows narrower by the day. Politicians are obligated by the nature of their jobs to satisfy public expectations, but the expectations that imagination creates grow more and more unattainable."

Even if one grants the truth of this unproven contention, one might marvel at the narrowness of McCurdy's vision. "Gaps between expectations and reality invite discontent," writes the author. Who would argue the point? But how much discovery and invention in the world of science and engineering occurs precisely because of the possibilities offered by imagination? One need not be a rocket scientist—literally or metaphorically—to appreciate the observation of the poet William Blake that "everything now called real was once imagined." ■

NORMAN WEINSTEIN writes about technology for WIRED, Educom Review, and Intelligent Agent.

# PROFESSIONAL SERVICES

## COMPUTERS

**Computer Engineering & Research, Inc** 617/237-6688  
Database Architects, specializing in building relational database applications  
Chuck Roth SM '66

**GE Capital Consulting** 617/951-1300  
Custom Software Development, Network Installation and Support  
Glenn Morgan SM '90

**Kenda Systems** 603/898-7884 800/I.E. KENDA [www.kenda.com](http://www.kenda.com)  
Global Quality Information Technology Resources  
Stephen K. Kenda '79

## ENGINEERING

**Brooks Acoustics Corporation** 860/647-0514  
Industrial noise control, Architectural Acoustics, Quiet Product Design  
[www.brooks-acoustics.com](http://www.brooks-acoustics.com) [bac@brooks-acoustics.com](mailto:bac@brooks-acoustics.com) Bennett M. Brooks '74

**GZA GeoEnvironmental, Inc.** 617/969-0050  
Engineers and Scientists DT Goldberg '54

**Kalman Saffran Associates** 617/527-2000 [www.ksal.com](http://www.ksal.com)  
Advanced Product Development - Electronic, Software, Mechanical Engineering and  
Information Systems Ronald G. Todd '74, SM '75

**Syska & Hennessy**  
Mechanical, Electrical and Sanitary Engineers  
John F. Hennessy II, P.E., SM '88

## CONSULTING

**Pugh-Roberts Associates** 617/864-8880  
Business Strategy, Market Analysis, Project Management, Management Training,  
Simulation Software Kenneth G. Cooper '72

**The Brattle Group** 617/864-7900  
Consulting services and expert testimony on economic, regulatory, and strategic  
issues to corporations and law firms world-wide. A. Lawrence Kolbe, PhD '79

## LEGAL

**Assadi Rahmanan & Marks, LLP** 800/655-0083 or [marksesq@juno.com](mailto:marksesq@juno.com)  
U.S. Visa and Permanent Resident status for Engineers, Scientists, Computer and  
Technical Professionals Stephanie Marks, former U.S. Immigration Judge

**Brown Raysman Millstein Felder & Steiner LLP**  
212/944-1515 or [rraysman@brownraysman.com](mailto:rraysman@brownraysman.com)  
New Media, Intellectual Property, Corporate Finance, Outsourcing, Litigation  
Richard Raysman '68

**Bromberg & Sunstein LLP** 617/443-9292  
Intellectual Property, Civil Litigation, Business & Health Law, specializing in the  
interface between Business and Technology Bruce Sunstein '65

**Kriegsman & Kriegsman** 508/877-8588  
Intellectual Property, Patent, Trademark, Copyright, Unfair Competition  
Biotechnology and Computer Law, Litigation and Licensing  
Edward M. Kriegsman '86

**Lahive and Cockfield, LLP** 617/277-7400 or [lc@lahcoc.com](mailto:lc@lahcoc.com)  
Intellectual Property, Patent, Trademark, Copyright, Unfair Competition  
Biotechnology and Computer Law, Litigation and Licensing W. Hugo Liepmann '57

**Lappin & Kusmer LLP** 617/330-1300 or [mlappin@lappinkusmer.com](mailto:mlappin@lappinkusmer.com)  
Intellectual Property and High Technology Law, including Patents, Technology  
Transfer, Trademarks and related matters  
Mark G. Lappin '64

**Weingarten, Schurgin, Gagnebin & Hayes** 617/542-2290  
Intellectual Property, Patent, Trademark, Unfair Competition, Copyright Law,  
Biotechnology, Computer, High Technology Law Charles L. Gagnebin SM '66

**Willard Alonzo Stanback, P.C.** 215/864-0870 [www.stanback-pc.com](http://www.stanback-pc.com)  
A New York Professional Corporation. Areas of law: Technology Law and Licensing;  
Intellectual Property (including Patents, Trademarks, Copyrights, and Entertainment  
Properties); and General Business Law Willard Stanback '85

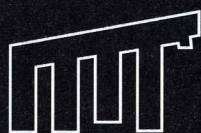
**William F. Green** 617/494-8332  
Intellectual Property, Patent, Trademark, Copyright, Contracts, Commercial Law,  
Employment Law, Start-ups David Bloore, CRE '89

**Wolf, Greenfield & Sacks** 617/720-3500 or [info@wgsllaw.com](mailto:info@wgsllaw.com)  
Intellectual Property, Patent, Trademark, Entertainment, Multimedia, Copyright,  
Unfair Competition Biotechnology, Computer Law, Litigation and Licensing  
James J. Foster '67

TO ADVERTISE IN THIS DIRECTORY, CONTACT AMANDA PRUGH AT 617-253-1421 OR [APRUGH@MIT.EDU](mailto:APRUGH@MIT.EDU)  
ALSO VISIT OUR ON-LINE LISTING AT: [HTTP://ALUMWEB.MIT.EDU/TR/LISTING.HTML](http://ALUMWEB.MIT.EDU/TR/LISTING.HTML)



## MIT's Building 20:



1943-1998

Next summer, MIT's Building 20, built as a "temporary" facility in 1943, will be taken down and pass into history. But this legendary structure — MIT's "Magical Incubator" — won't be forgotten.

During World War II, the building was built to house the Radiation Laboratory, and it's there that MIT engineers refined the development of radar that helped win that war. Since then, an amazing assortment of laboratories, organizations, student groups, and offices has taken shelter in the wings of MIT's Building 20, many of which led to important and groundbreaking developments.

On March 26-27, 1998, the MIT community will celebrate the remarkable story of MIT's Magical Incubator. Come remember the past and glimpse a future undreamed of fifty years ago, now materializing with amazing speed.

## The Magical Incubator

### Thursday, March 26

Join us for Building 20 commemorative displays and a Welcome Reception.

### Friday, March 27

A full-day program highlighting special developments over the decades, tours, demonstrations, lunch, and a last chance to walk through Building 20.

#### Speakers include:

Professor Peter Demos '51  
Professor Robert Gallagher '57  
Professor Morris Halle  
Alan Kotok '62  
Professor Jerome Lettvin '47  
Professor Walter Morrow, Jr. '49  
Provost Joel Moses '67  
Professor Paul Penfield, Jr. '60  
Professor Gill Pratt '83  
Ted Saad '41, Rad Lab staff member  
Professor Rainer Weiss '55  
James Worden '89

The festivities conclude on Friday with a Banquet on campus honoring Maria and Ray Stata '57, Founder and Chairman, Analog Devices, Inc. and will feature a look ahead at the complex for computer, intelligence, and information sciences, to be named for Maria and Ray Stata '57, which will rise on the site of Building 20 over the next few years.

#### Registration Information

To receive a registration brochure or more information, please call Vera Sayzew at (617) 253-4624 or visit <http://www-eecs.mit.edu/building/20>. Hurry, you must register by March 1, 1998 to get the reduced registration fee of \$100.

MIT is collecting reminiscences of Building 20. To submit your favorite story, please email it to [magicalincubator@mit.edu](mailto:magicalincubator@mit.edu) or visit <http://www-eecs.mit.edu/building/20/anecdote-form.html>.



# Technology Marketing Group Inc.

We Find New Markets for  
New and Existing Technologies

## SPECIAL EMPHASIS ON:

Specialty Chemicals, Electronics,  
Communications, Instruments,  
Paper, and Professional Services

## EXPERIENCE IN 100 INDUSTRIES

Ask About Our  
"FIND ME  
SOME NEW  
MARKETS"  
Service

### TECHNOLOGY MARKETING GROUP INC.

77 Great Road, Suite 202 ■ Acton, Massachusetts 01720

Tel: 978-263-0648 ■ Fax: 978-263-1810

[www.technology-marketing.com](http://www.technology-marketing.com)



MIT'S  
TECHNOLOGY REVIEW  
**CAREERS**

**MIT'S TECHNOLOGY REVIEW  
CAREER CLASSIFIEDS AND  
RECRUITMENT ADVERTISING**

**ISSUE AND CLOSING DATES**

ISSUE	RESERVATION DATE:	PUBLICATION DATE:
Jan/Feb	November 14	December 24
Mar/Apr	January 15	February 18
May/June	March 16	April 22
July/Aug	May 15	June 24
Sept/Oct	July 15	August 19
Nov/Dec	September 15	October 21

**DISPLAY RECRUITMENT  
ADVERTISING**

For rates and information contact:

Charles Dupree  
TEL 404-303-0179  
FAX 404-303-5124  
TRADVERTISING@MIT.EDU

RATES: \$35 per line, 5-line minimum.  
(One line equals approximately 50 characters.)

To submit a CAREERS classified ad, mail, fax,  
or email text and billing information to

MIT's Technology Review  
Attn: Elizabeth Surano  
MIT Building W59-200  
77 Massachusetts Avenue  
Cambridge, MA 02139  
FAX: 617-258-5850  
TRADVERTISING@MIT.EDU

Include issue date and choose either the  
POSITIONS OPEN, POSITIONS NEEDED, MEETINGS  
or ANNOUNCEMENTS category. Technology  
Review will typeset the ad and provide you  
with a cost estimate.

VISIT TR'S ONLINE CAREER CENTER AT  
<http://web.mit.edu/techreview/>

All Career Classifieds and Recruitment Ads  
will appear on Technology Review's  
World Wide Web Home Page for FREE.

**DIRECTOR OF  
INFORMATION TECHNOLOGY**

The Sloan School of Management seeks an individual to manage the full range of computer services required to support its teaching and research programs and internal administrative functions. Will participate in identifying and setting priorities for user needs; define system requirements and support; and manage, direct, and advise on the following: user education/training, hardware/software standards, system capability, documentation, and related matters. Will also develop and manage an overall business plan and budget for computer services, be responsible for purchasing and vendor relations, and act as liaison to MIT Information Systems and other management schools.

**Requirements:** a master's degree or equivalent education and experience and five to ten years of senior management computing experience. Must have project management experience. Knowledge of university environment preferred. Knowledge of state-of-the-art computer technologies needed, as is demonstrated experience with micro computers and/or mainframe technologies. Excellent oral and written communications skills required.

Interested candidates should submit a resume and cover letter referencing Job No. 97-0008A to:  
**Jennifer Walsh, MIT Personnel, PO Box 391229, Cambridge, MA 02139-0013.**



**Massachusetts Institute of Technology**  
An Equal Opportunity/Affirmative Action Employer  
Non-Smoking Environment

**MIT**

**Information  
Technology &  
Management  
Consulting**

We are a fast-growing firm that combines IT and Management Consulting. If you...

- Understand the power of IT, and want to apply it to business problem solving
- Have graduated from a top academic program (Masters or PhD preferred)
- Can visualize complex systems
- Have 3+ years of experience in project management
- Are looking for a fresh, fast-moving company with exceptional opportunities

We invite you to find out more about us:



**PRINCETON CONSULTANTS**  
[www.princeton.com](http://www.princeton.com)

**Your Future Starts Here.**

Philips Electronics is a diverse, global company with annual sales exceeding \$40 billion. By making high technology and consumer electronics, media and lighting products better, our more than 30,000 North American employees enhance the lives of millions of people.

Philips Electronics is admired world-wide for its cutting-edge engineering. And we have the awards to prove it. We recently won our second Engineering Emmy Award for developing the Ground Alliance Digital TV Standard. It's an example of how our research and advanced development can result in benefits for everyone. And indicates the kind of cutting edge projects you could be part of, doing research on technologies as diverse as power IC's and electronic ballast, embedded software development, and digital television. It's the kind of highly stimulating environment that leading scientists need to thrive.

Philips continues to develop a range of product-related technologies such as:

- Advance Television Systems
- Display Systems
- Lighting Electronics
- Electronic Power Systems
- Multimedia Networks
- Software and Services
- Digital Video Communications
- Image Processing

Some of the most impressive electronic innovations we produce at Philips get their start here in the New York area.

If you are an engineering or sciences graduate (M.S. or Ph.D.) with excellent academic credentials, you should consider bringing your career to a place where it can grow. Please send your resume to:  
**Human Resources, College Recruitment, Philips Research, 345 Scarborough Road, Briarcliff Manor, New York 10510; Fax: (914) 945-6400. Or e-mail: [sacs@philabs.philips.com](mailto:sacs@philabs.philips.com)**

We are an equal opportunity employer m/f/d/v-minorities and women are encouraged to respond.

*Let's make things better.*



**PHILIPS**

# In-the-box thinkers wanted.

It takes keen strategic, creative and technical minds to put big brands like Kraft, Kodak, L.L.Bean and IBM on the Web. **Strategic Interactive Group** has managed to do exactly that in just two years. We're fast-growing, award-winning, and... (drumroll please)...we're looking to add to our 200-person team.

If you're interested in joining one of the largest, full-service interactive agencies in the country, get in touch with us today.



We have measurement technology, programming & development, IS, production, marketing, and creative positions open in our Boston, New York, and San Francisco offices. Email [tdreier@sig.bsh.com](mailto:tdreier@sig.bsh.com), or mail to:

Terri Dreier  
Strategic Interactive Group Inc.  
The Prudential Tower  
800 Boylston Street  
Boston, MA 02199

## Strategic Interactive Group

A Bronner Slosberg Humphrey Company

Fax: (617) 867-1111 [www.sig.bsh.com](http://www.sig.bsh.com) SIG is an Equal Opportunity Employer. M/F/H

Every child deserves the best opportunities life has to offer. Especially yours.

The odds of her becoming an astronaut and reaching the stars are out of this world. But the chances are more than 1 in 4 that your baby isn't protected against childhood diseases like polio, measles, chicken pox, tetanus and others.

So, even if you're sure your child is up to date and on schedule with her baby shots, ask your doctor at every visit. It couldn't hurt.

In fact, it could give her the chance to grow up to be whatever she wants to be.

Even if it's something out of this world.

**If you want her to have a shot at reaching the stars, she needs to get her baby shots now.**



Even if you're sure, ask again. 1-800-232-2522

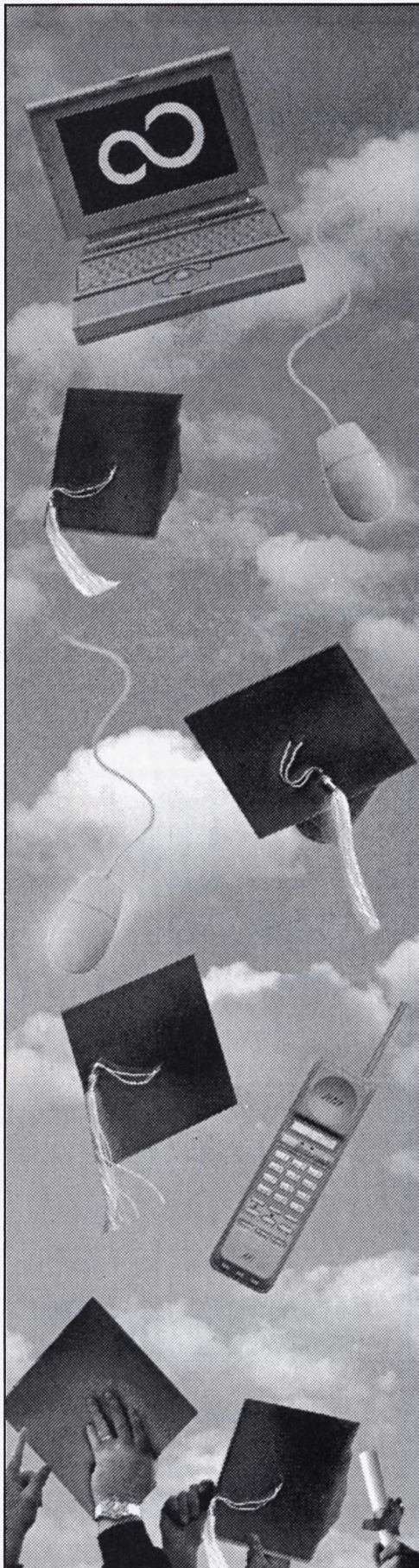


## Don't miss your chance to make a connection!

*Place your recruitment display ad here.*

*For deadlines and information on rates, contact Charles Dupree at 404-303-0179 [tradvertising@mit.edu](mailto:tradvertising@mit.edu)*

TechnologyReview  
**Careers**



You've earned your degree.

# Now Master The Technology.

## Graduate To The Network Of Knowledge at Fujitsu Network Communications.

We're headquartered in the heart of the Telecom Corridor in Richardson, Texas (a suburb of Dallas), and have established state-of-the-art facilities in California, New York and North Carolina. Enroll with us today and you'll experience new worlds of knowledge, opportunity and success.

Our parent company, **Fujitsu Limited**, is the world's largest computer company and an international leader in the telecommunications and microelectronics industries. At **Fujitsu Network Communications**, we specialize in the development and manufacture of some of the most dynamic digital fiber optic transmission and broadband switching equipment in the universe.

Our mission is to achieve industry leadership by continuing to develop innovative telecommunications products that utilize our world-leading technologies while providing a dynamic professional environment that recognizes the importance of long-term stability, employee involvement and personal growth.

If you're a forward-thinking graduate with a degree in computer science or engineering, or if you are an undergraduate working toward one of these areas, we're anxious to meet with you. Opportunities are available in Santa Clara, CA, Raleigh, NC, Pearl River, NY and in Richardson, TX for the following areas:

**Network Management**

**Hardware**

**Test & Verification**

**Wireless**

**Software**

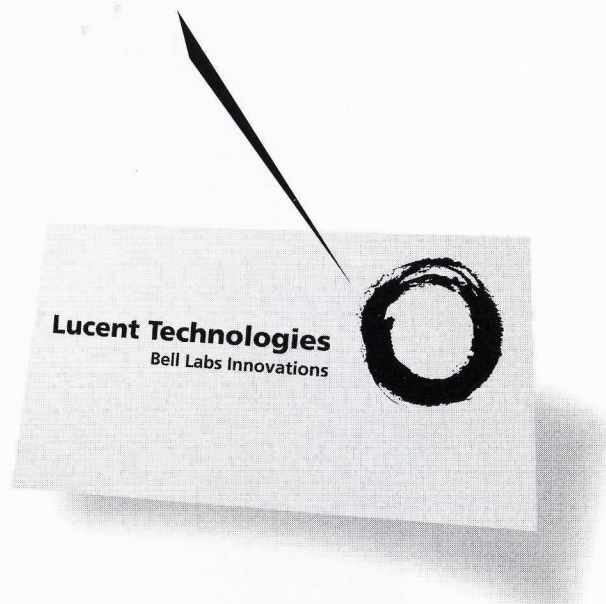
**Technical Support**

Your final education in technology begins with **Fujitsu Network Communications**. We offer competitive salaries, relocation packages, educational assistance, wellness programs and company condos. Benefits include, medical/dental/vision insurance, 401(k) and retirement plans and annual company paid bonuses. Applicants should send or fax their resume to: Fujitsu Network Communications, Attn: College Relations, 2801 Telecom Parkway, Richardson, TX 75082; fax (972) 479-3055. For additional information on employment, please look us up on our website at [www.fujitsu.com/FNC](http://www.fujitsu.com/FNC). No phone calls please. Equal Opportunity Employer, M/F/D/V.

# FUJITSU

Network Communications

# are **you** our next **innovator?**



Innovation. It's our business at Lucent Technologies. Innovations in global communications. Innovations in engineering and software development. Innovative strategies in marketing, sales, and business. The list goes on.

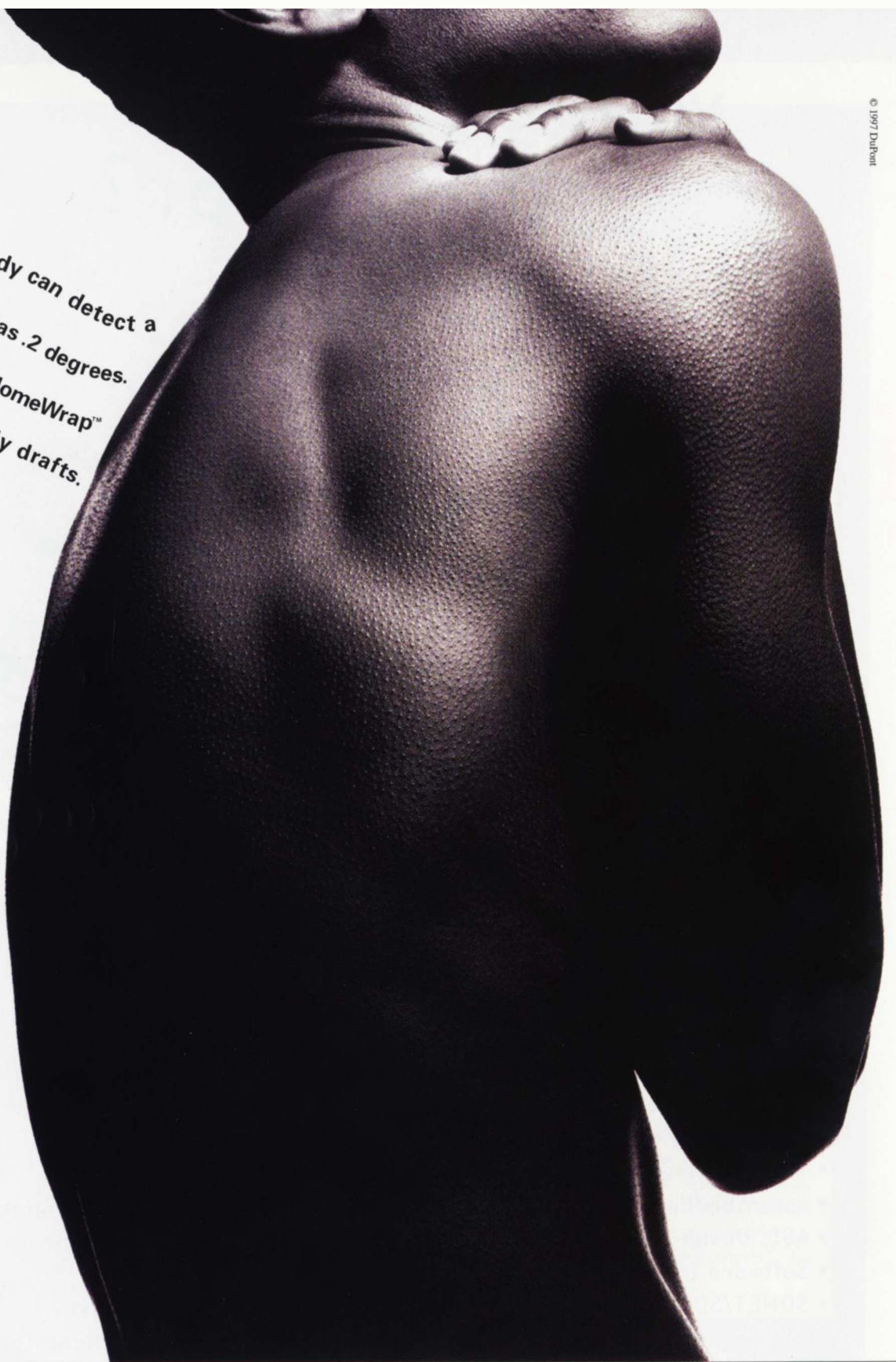
At Lucent, we're creating the next generation of telecommunications today with one breakthrough after another. From the first transistor to the latest Internet technology, our history of Bell Labs innovations continues at full speed. And you could be our next innovator.

Currently, we have opportunities available throughout our organization for:

- Security Consultants
- Security Engineers
- Project Managers
- Sales Account Executives
- Software Developers
- Process Engineers
- Test Engineers
- Assembly/Packaging Engineers
- ASIC Design Engineers
- Software Integration Test Engineers
- SONET/SDH Digital ASIC Design Engineers
- DSP Engineers
- SAP R/3 Specialists
- Marketing Managers
- Market Analysts
- Systems Analysts
- Failure Analysis Engineers
- Mechanical Engineers
- Design Engineers
- Firmware Design Engineers
- Serviceability Engineers
- RF Engineers
- Systems Architects
- Telecommunications Technicians

Come experience the Information Revolution firsthand. Send your resume to: Lucent Technologies, attn: Employment Manager, Dept. MIT/4001/97, 283 King George Road, Room B2C76, Warren, NJ 07059. Or apply on-line at [www.lucent.com](http://www.lucent.com) Lucent is an equal opportunity employer.

The human body can detect a  
change as tiny as .2 degrees.  
DuPont Tyvek® HomeWrap™  
keeps out chilly drafts.



[www.dupont.com](http://www.dupont.com)



Better things for better living

Tyvek® is a DuPont registered trademark for its brand of housewrap. Only DuPont makes Tyvek®.